Chapin

TRANSACTIONS

OF THE

AMERICAN SOCIETY

OF

CIVIL ENGINEERS.

(INSTITUTED 1852.)

VOL. XVIII.

JANUARY TO JUNE, 1888.

NEW YORK:
PUBLISHED BY THE SOCIETY.

1888.

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(Vol. XVIII.—January, 1888.)

DISPOSAL OF SEWAGE IN MASSACHUSETTS.

By FREDERIC P. STEARNS, M. Am. Soc. C. E.

READ AT THE ANNUAL CONVENTION JULY 2D, 1887.

The announcement that the disposal of sewage is one of the subjects to be discussed at the Convention this year, induces me to present to the Society a statement of the present status of this question in Massachusetts, with a brief reference to the action of the State in the matter in the past.

Massachusetts is, with one exception, the most densely populated of the States, as will be seen by the following table of the leading States in this respect:

STATE.	Population per square mile (1880).
Rhode Island	255
Massachusetts	222
New Jersey	152
Connecticut	129
New York	107
Pennsylvania	95
Maryland	95

In 1885 the population per square mile in Massachusetts was 242. It is now more densely populated than France or Germany, and is not far behind Italy or Great Britain and Ireland.

Ohio Pop 3200.000 / 40760 = 78 per sq mile

The water power of the streams has been largely developed, and the many manufactories using the water add their refuse to the streams.

For the past fifteen or twenty years it has been evident to the sanitarians who have considered the subject, that within a comparatively brief period it would be necessary to adopt some decisive measures to protect the purity of the streams.

In 1871 the State Board of Health examined one of the valleys of the State with reference to the pollution of a stream used for a water supply.

In 1872 the Legislature passed an act providing for a commission of engineers to report plans for the sewerage and water supply of the metropolitan district. They also created a commission to devise a plan for preventing the pollution of a small stream near Boston, where the co-operation of two or more cities was necessary.

In 1873 the State Board of Health, in answer to a resolve of the Legislature of 1872, submitted a lengthy report on the disposal of sewage, its utilization, the sanitary effect of draining the same into the streams and the increasing joint use of water-courses for sewers and as sources of water supply.

Since 1873 the reports of this Board have contained a large amount of valuable matter on the general subject of the disposal of sewage and much information as to the present condition of Massachusetts' rivers as regards pollution.

In 1878 a law was passed forbidding the future pollution of waters used for a domestic water supply within twenty miles above the point of taking. This law does not apply to the Merrimack and Connecticut Rivers.

In 1882, in answer to a resolve of the Legislature, the State Board of Health reported upon the pollution of the Blackstone River by the city of Worcester, recommending that it be required to purify its sewage before turning it into the stream. The same year a commission, which was appointed to consider the drainage of the Mystic and Charles River valleys, submitted their report.

In 1884 the pollution of the Blackstone River was the subject of extended hearings before a legislative committee. The same year the Massachusetts Drainage Commission was appointed "for the purpose of considering and reporting a general system of drainage for the relief of the valleys of the Mystic, Blackstone and Charles Rivers, and for the

protection of the public water supplies of the cities and towns situated within the basins of said rivers." The Commission, which was also to consider the question of the disposal of sewage, could at its discretion include other valleys in its examinations, and was given nearly two years and a liberal appropriation for its work.

The Commission appointed as its chief engineer, Mr. Eliot C. Clarke, M. Am. Soc. C. E., and his very thorough and comprehensive report was submitted to Joseph P. Davis and Rudolph Hering, Members Am. Soc. C. E., who were asked to act as consulting engineers.

Of the more important recommendations of this Commission, two were adopted by the Legislature of 1886.

By one of these the City of Worcester is required, not later than the summer of 1890, to so treat its sewage before discharging it into the Blackstone River that it shall not create a nuisance or endanger the public health.

The engineer of this city, Mr. C. A. Allen, M. Am. Soc. C. E., has recently made a report recommending that chemical precipitation be adopted.

By the adoption of the second recommendation of the Commission the State has now a general law relating to the supervision of water supply and sewerage, its execution being intrusted to the State Board of Health.

The foregoing indicates the growth of the sewerage question in Massachusetts.

The general law referred to is the first of its kind in the country, so far as the writer is informed, and some space will be devoted to a statement of its provisions and of its execution up to the present time.

The law is given in full as an appendix.

The duties of the Board of Health under this law may be stated concisely as follows:

First.—To have the general care and oversight of inland waters.

Second.—To recommend legislation and suitable plans for systems of main sewers.

Third.—To cause examinations of the waters of ponds and streams to be made.

Fourth.—To recommend measures to prevent the pollution of waters.

Fifth.—To conduct experiments on the purification of drainage.

Sixth.—To conduct experiments on the disposal of manufacturing refuse.

Seventh.—To consult with and advise the authorities of cities and towns and others as to the most appropriate source of water supply and

the best practical method of assuring the purity thereof or of disposing of their sewage, having regard to the present and prospective needs of cities, towns, etc., affected thereby.

Eighth.—To consult with and advise manufacturers with reference to the disposal of manufacturing refuse.

Ninth.—To bring to the notice of the Attorney-General all omissions to comply with existing laws.

The law further provides that authorities of cities and towns, and all others intending to introduce systems of water supply or sewerage, shall submit to the Board outlines of their proposed plans or schemes in relation to these subjects; and that manufacturers intending to engage in any business, drainage or refuse from which may tend to cause the pollution of any inland waters, shall also give notice to the Board of their intentions in the premises.

The Board consists of seven members, of whom one is a prominent civil engineer, one a physician who for many years has made water supply and sewerage questions a special study, one a lawyer and the others physicians and business men.

The engineering staff of the Board at the present time consists of Joseph P. Davis, M. Am. Soc. C. E., Consulting Engineer; the writer, Chief Engineer, and one permanent and two temporary assistants.

The work of the Board during the nine months in which the law has been in practical operation has consisted chiefly in advising cities, towns and public institutions about proposed plans of water supply and sewerage, though they have begun upon monthly chemical examinations of waters from all public water supplies and the more important rivers; these examinations to be supplemented by biological and microscopic work by experts. It is hoped that much information may be gained by these systematic researches. Plans are under consideration for some accurate experiments on the disposal of sewage at one of the public institutions.

The proposed systems of sewerage submitted by cities and towns have included combined and separate systems, and the disposal of sewage by purification upon land and by direct discharge into water-courses; all of which have been approved where, after thorough examination, they appeared to be best suited to the circumstances of the cases, and nearly all have been disapproved under other circumstances.

The experience thus far gained has helped to emphasize the need, well known before, of some restriction upon the discharge of polluting matters into the ponds and streams of the State, as well as to show for-

cibly the difficulty of making this restriction by any laws applied without discrimination to all cases. The plan adopted of making this restriction through the agency of a Board having power to examine each case with the aid of experts and decide each upon its merits seems to be the best that could be adopted and one to be recommended to other States.

In Massachusetts the Board is given advisory and not mandatory powers ; whether this will be sufficient or not is a question. It has proved sufficient for the Massachusetts Railroad Commission for many years and for the Board during the brief time that the law under consideration has been in operation and I think it will continue to be so.

Up to the present time only two towns in Massachusetts, Lenox and Medfield, have built works for purification, and these, with the public institutions, notably the reformatories at Concord and Sherborn and the Insane Hospital at Worcester, furnish the only important examples of sewage purification in the State.

During the next few years several other examples will probably be furnished, since Worcester is required by law to purify its sewage within three years, and the city of Brockton and the towns of Milford, Framingham and Marlborough are proposing to dispose of their sewage upon land. Lenox is proposing to build additional works, and many other cities and towns desirous of providing sewerage facilities, realize that they must adopt some purification processes.

APPENDIX.

COMMONWEALTH OF MASSACHUSETTS.

[Chap. 274.]

An Act to protect the purity of inland waters.

Be it enacted, etc., as follows:

Section 1. The State Board of Health shall have the general oversight and care of all inland waters and shall be furnished with maps, plans and documents suitable for this purpose, and records of all its doings in relation thereto shall be kept. It may employ such engineers and clerks and other assistants as it may deem necessary; provided, that no contracts or other acts which involve the payment of money from the treasury ot the Commonwealth shall be made or done without an appropriation expressly made therefor by the general court. It shall annually on or before the tenth day of January report to the general court its doings in the preceding year, and at the same time submit estimates of the sums required to meet the expenses of said board in relation to the care and oversight of inland waters for the ensuing year; and it shall also recommend legislation and suitable plans for such systems of main sewers as it may deem necessary for the preservation of the public health and for the purification and prevention of pollution of the ponds, streams and inland waters of the Commonwealth.

Sec. 2. Said board shall from time to time as it may deem expedient, cause examinations of the said waters to be made for the purpose of ascertaining whether the same are adapted for use as sources of domestic water supplies or are in a condition likely to impair the interests of the public or persons lawfully using the same, or imperil the public health. It shall recommend measures for prevention of the pollution of such waters and for removal of substances and causes of every kind which may be liable to cause pollution thereof, in order to protect and develop the rights and property of the Commonwealth therein and to protect the public health. It shall have authority to conduct experiments to determine the best practical methods of purification of drainage or disposal of refuse arising from manufacturing and other industrial establishments. For the purposes aforesaid it may employ such expert assistance as may be necessary.

Sec. 3. It shall from time to time consult with and advise the authorities of cities and towns, or with corporations, firms or individuals either already having or intending to introduce systems of water supply or sewerage, as to the most appropriate source of supply, the best practical method of assuring the purity thereof or of disposing of their sewage, having regard to the present and prospective needs and interests of other cities, towns, corporations, firms or individuals which may be affected thereby. It shall also from time to time consult with and advise persons or corporations engaged or intending to engage in any manufacturing or other business, drainage or refuse from which may tend to cause the pollution of any inland water, as to the best practical method of preventing such pollution by the interception, disposal or purification of such drainage or refuse; provided, that no person shall be compelled to bear the expense of such consultation or advice, or of experiments made for the purposes of this act. All such authorities, corporations, firms and individuals are hereby required to give notice to said board

of their intentions in the premises, and to submit for its advice outlines of their proposed plans or schemes in relation to water supply and disposal of drainage or refuse. Said board shall bring to the notice of the attorney-general all instances which may come to its knowledge of omission to comply with existing laws respecting the pollution of water supplies and inland waters and shall annually report to the legislature any specific cases not covered by the provisions of existing laws, which in its opinion call for further legislation. [Approved June 9, 1886.]

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SEWAGE DISPOSAL.

By Charles A. Allen, M. Am. Soc. C. E.
Read at the Annual Convention—July 2d, 1887.

In the fall of 1883 I received instructions from the City Council of the City of Worcester, Mass., to visit Europe, for the purpose of examining the various methods of sewage disposal in use there, the information so obtained to be used in suits brought against the city, for polluting the Blackstone River, and also to be used in determining the best method of disposing of the sewage of the city, in case it should be found necessary in the course of time, so to do. In September, 1886, I received instructions to prepare a report upon the subject, and to recommend what, in my opinion, would be the most practicable system of disposal for the city to adopt. The report has been made and published, and as it presents my views upon the subject, I shall take the liberty of quoting largely therefrom, taking care to use only such portions of the report as bear upon the general subject, and not upon local conditions.

As the history of sewage purification in England is exceedingly interesting, and dates back nearly half a century, a brief review will perhaps be instructive.

Early in the present century it became apparent that, owing to the great pollution of the rivers and streams flowing through the densely

populated districts, some method of purification must be adopted; coupled with this, was the belief that large sums of money could be made out of the sewage, by devising some method of converting it into a fertilizer.

A large amount of capital was invested in works for this purpose, nearly all of which was lost.

Commissions appointed by towns, cities and the general government, investigated the subject, and made elaborate reports and recommendations. A bare quotation of the titles of these would fill quite a volume and is out of the question here.

By most of the methods tried, it was found possible to extract the solid matters contained in the sewage, but when this was accomplished, it was found that the extract, in many instances, was valueless, and that the effluent obtained, in every case, was anything but pure.

I will give a few examples of the early efforts made, as they bear upon the subjects of sedimentation and mechanical filtration, which have been suggested as possible means of purifying sewage.

At Aldershot and Rugby, the sewage was strained through planks perforated with holes $\frac{3}{4}$ of an inch in diameter, but the purifying effect was slight, for the amount of suspended matter was only reduced from 43.77 grains per gallon to 35.01 at Aldershot, with about the same result at Rugby, while the organic matter was 14.02 grains per gallon, before, and 8.77 grains per gallon after, treatment.

Even with a more elaborate system of filtration, as was practiced at Merthyr-Tydfil, where the sewage passed through a filter of coarse iron slag, about three feet thick, and then through another filter of coarse vegetable charcoal, the suspended matters were reduced from 169.81 grains to 32.31 grains per gallon; but the soluble matters were not affected.

A Mr. Strong, of Glasgow, designed an apparatus for filtering sewage, the filtering medium being coal ashes.

The filtration was upward, so that the solid matter was retained in the lower part of the filter. This apparatus was tried at a public institution in Glasgow, having about two hundred inmates; the effluent was very free from suspended matters, but the soluble portion of the sewage escaped untouched.

At Birmingham sand filters were at one time used with about the same success, while at Chelmsford and Belston, clinkers and ashes were

employed. It was found that if the filtering material was fine in its texture, it very soon clogged; and if coarse, it failed to remove a large amount of matter carried in suspension.

Other examples of mechanical filtration might be quoted, if necessary, the result obtained in every instance being about the same.

Birmingham originally tried subsiding tanks. They were arranged so that the sewage was discharged into a tank about ninety feet long and fifty feet wide; from thence it flowed over a weir guarded by floating boards placed for the purpose of intercepting floating matters, into a tank of similar dimensions, and then over a like weir into a third tank (30 feet wide and 150 feet long), from this into another of about three times the capacity of the last, and then over a weir into the effluent channel which conveyed it to the River Rea. In this manner a large portion of the heavier matters in the sewage was deposited in the tanks, for it took about two hours for the sewage to pass through the entire series; but still the effluent water was very offensive and was the cause of serious nuisance to those who had an interest in the river below the works, or as the report of Dr. Lethby states: "The whole of the works are in a very unsatisfactory condition, and are a serious nuisance to the neighborhood."

This is only one of many examples that might be cited.

The combined system of sedimentation and filtration was scarcely more successful. At Coventry, for instance, the sewage was first allowed to stand in settling tanks; it was then filtered through a lateral filter of coarse gravel (running the whole length of the tank), 150 feet long, 49 feet wide, 9 feet deep. From this tank the sewage ran into another of of the same dimensions, from which it passed through a filter of the same size as the first, of finer gravel and from that into the stream. The sludge was mixed with the ashes and sweepings of the town and commanded a good price as a fertilizer, the works being nearly self-supporting, but the purification was so imperfect that they were abandoned.

At Uxbridge the sewage after standing in a subsiding tank was filtered through charcoal. This was also found to be so imperfect that it was soon abandoned.

The above facts were obtained from reports.

The history of sewage treatment in England is full of just such failures as are quoted above; for, while some of the methods of artificial filtration and sedimentation were nearly self-supporting, none of them

paid, and all of them produced so poor an effluent that they were soon abandoned.

As it became evident that simple subsidence and filtration could not be made to pay, more attention was given to irrigation and chemical precipitation. Where irrigation was adopted it was hoped that by applying the sewage to the land and raising crops a fair profit could be made and a pure effluent obtained at the same time. And from that time until the present day this effort has been earnestly made. The result is, however, that while in the majority of cases under proper and careful management, and when the climatic conditions are favorable, a good effluent is obtained, in no case, so far as I am able to learn, has a profit ever been made, for the sewage comes night and day, in season and out of season, during rainy weather and dry weather, and demands constant attention. The effect upon vegetation can be imagined, for often the land is soaked with about twice the amount of water that comes in the rainfall besides the rainfall itself. There are exceptions to this, of course, but the above statement is true in most cases.

Most of the vegetables grown are very coarse and are used principally for feeding cattle. Experience has shown that to obtain anything like a good effluent it is necessary to provide one acre of land for each one hundred inhabitants in the district drained, that the land so used shall have a subsoil of gravel or sand, that in many cases it shall be properly underdrained, the drains being not less than five feet below the surface of the ground, and that in times of heavy storms the sewage shall be filtered through beds especially prepared for that purpose.

In many cases, however, this latter method is not employed, the sewage being simply turned into the streams during storms.

Meanwhile the purification of sewage by chemical precipitation received the earnest attention of a large number of scientific men, the hope being entertained that by the introduction of different chemicals into it, a fair profit from the sale of the sludge as a fertilizer would be realized, and at the same time a good effluent obtained.

Companies were formed, and different processes patented, nearly all of these producing a fair effluent, but they were so expensive that most of the companies lost money, and but few of them survived. It was found that, while the introduction of chemicals, to a certain extent, made the sludge more valuable as a fertilizer, the income derived from the improvement was not great enough to anywhere near pay the oper-

ating expenses. In fact, the disposal of the sludge was the great drawback to this method of sewage treatment; at the present time there is very little sale for it, and in a great many places the farmers will not draw it away if given them.

As before stated, most of the processes at first tried were abandoned, as it was found that the best results were obtained by either one of the three following methods:

"The Lime Process," which is the most extensively used, the "Coventry Process," and the "A B C Process." This latter method is very expensive, and is not in general use.

While the disposal of the sludge was, and in some cases is, a great drawback to this method of treatment, still there is sufficient merit in the system to induce about fifty cities and towns in England, to adopt it in some form.

The old method of disposing of the sludge is open to quite serious objections, not only from an economic, but from a sanitary point of view. The sludge, which in all cases contains about 90 per cent. of water, is spread upon land and allowed to dry sufficiently to handle readily, or else is dried in vats especially prepared for the purpose. In a short time it becomes more or less offensive, especially in warm weather; and if in close proximity to buildings, is a nuisance. By the adoption of sludge presses, however, this difficulty is entirely removed, for a large percentage of the moisture is extracted, leaving the compressed cake in a condition to be readily handled.

It is also very much more valuable as a fertilizer, as the cakes can be taken and used when fresh, while by the old process of sun-drying, a large percentage of the manurial qualities of the sludge is lost by the evaporation and exposure to the air.

At the present time, chemical precipitation is recognized in England, as being one of the best methods for treating large quantities of sewage.

Dr. Frankland, in 1870, suggested downward intermittent filtration, as a means of purifying sewage; and this method of purification was soon adopted by Mr. Bailey Denton in his practice.

It differs from broad irrigation, in that, instead of spreading sewage over a large surface of ground, and having in view the raising of crops, as one of the principal objects to be attained, a small area of porous land is selected and thoroughly underdrained, the tract being

divided so that while the sewage is applied to one section, the other has a chance to rest, the object of intermittence being to thoroughly aerate the bed not in use, so that when the sewage is again applied, the soil will be in a fit condition to purify it.

This method has been adopted in several instances, where the amount of sewage to be treated is small, and in many cases, in connection with irrigation and precipitation. It is claimed by the advocates of this method that to properly purify the sewage the land must be porous, and must be thoroughly underdrained, the drains being at least five feet below the surface of the ground.

It is claimed that the sewage from not more than one thousand people can be applied to each acre of prepared land, but this is not advisable unless the solids are to some extent removed. And crude sewage from not more than five hundred persons can be applied to each acre, with good prospects of success.

It will be seen that there are three distinct methods now employed abroad for treating sewage, they being subject to such modifications as are necessary in designing works for different localities.

Irrigation and chemical precipitation are the most extensively employed, downward intermittent filtration being principally used as an auxiliary to one of the other methods, although, as stated, there are places where a comparatively small quantity of sewage is to be treated, where this method alone is employed.

Under favorable conditions, and when carefully and judiciously managed, the effluent obtained by either process is fairly satisfactorily, sufficiently so in most cases, to warrant its discharge into a stream not used for water-supply purposes.

The expense of treatment being considerable, however, the tendency is to use the works so as to bring in the greatest income. This, judging from the results obtained abroad, should never be allowed, for it has been found that as the income increases, the purity of the effluent is very likely to be affected, owing to the fact that it is very rarely the case, that all the sewage can be applied to the land without injury to plant life. This is the reason why, on most sewage farms, the sewage is turned into the nearest stream during stormy weather, or when the ground becomes surcharged with water from any cause.

Now the conditions, climatic and other, that exist in central Massachusetts, are not as favorable to the proper treatment of sewage by

irrigation or by filtration, as in England and France, or even in Germany, at Berlin and Dantzic.

Although the claim has been made in reports upon the subject that there is no material difference, I think, however, that there is a reasonable doubt about this. The following statements of the difference in temperatures, will show a decided difference in climatic conditions during the winter months. The temperatures at Dantzic were obtained from Mr. Aird, the manager of the farm at that place, and are official; while the temperatures for Massachusetts were taken from the records at Worcester.

The following table gives the differences in temperature for five winters, beginning with December 1st, 1877, and ending March 31st, 1883:

Dantzic.	Average Monthly Temperature.	Worcester.	Average Monthly Temperature.
December, 1878,	34 degrees Fahr.	December, 1878,	25 degrees Fahr.
January, 1879,	28 "	January, 1879,	20 "
February, "	32 "	February, "	20 "
March, "	33 "	March, "	30 "
Average by mos.	31.75 "	Average by mos.	23.75 "
December, 1879,	27 degrees Fahr.	December, 1879,	28 degrees Fahr.
January, 1880,	29 "	January, 1880,	30 "
February, "	31 "	February, "	27 "
March, "	36 "	March, "	29 "
Average by mos.	30.75 "	Average by mos.	28.5 "
December, 1880,	34 degrees Fahr.	December, 1880,	20 degrees Fahr.
January, 1881,	23 "	January, 1881,	16 "
February, "	28 "	February, "	23 "
March, "	3[illegible] "	March, "	32 "
Average by mos.	29.5 "	Average by mos.	22.75 "
December, 1881,	34 degrees Fahr.	December, 1881,	33 degrees Fahr.
January, 1882,	37 "	January, 1882,	21 "
February, "	38 "	February, "	25 "
March, "	44 "	March, "	32 "
Average by mos.	38.25 "	Average by mos.	27.75 "
December, 1882,	26 degrees Fahr.	December, 1882,	23 degrees Fahr.
January, 1883,	27 "	January, 1883,	18 "
February, "	30 "	February, "	22 "
March, "	26 "	March, "	23 "
Average by mos.	29.75 "	Average by mos.	21.5 "

It will be noticed that with the exception of the winter of 1879-80, the mercury ranged much lower here (Central Massachusetts) than at Dantzic, a difference of from 7 degrees to 8 degrees Fahr. for the entire season, being the general amount. This, of course, makes a great difference in frost penetration, and adds to the liability of the ground remaining frozen.

An examination of the accompanying tables of daily temperatures shows that in the five years covered by the tables given above, at Dantzic there were only three days during that period that the thermometer registered below zero, the extreme being 4 degrees below, while at Worcester, during the same period, there were forty days below zero, with an extreme of 18 degrees below.

At Dantzic, there were thirty-eight days in which the thermometer registered from zero to 10 degrees above, while at Worcester, there were 124 days.

At Dantzic, there were 73 days in which the temperature was between 10 and 20 degrees above zero, while at Worcester there were 164 days.

While there were 346 days at Dantzic in which the thermometer registered between 20 and 32 degrees above, at Worcester there were 221 days.

The total number of days covered by the observations in the five years was 606. Of this number Dantzic had 460 below the freezing point, or about 75.9 per cent., while Worcester had 542 days or 89.4 per cent.

While Dantzic had only 114 days below 20 degrees, or 18.8 per cent. Worcester had 328, or 54.1 per cent.

At Berlin the sewage is stored in large reservoirs during the severest portion of the winter, no attempt being made to purify by irrigation, while at Dantzic it is constantly applied to the land without regard to the weather, the manager stating that while the action of the frost interfered somewhat with the operation of the works, still the periods of extreme cold were of so short duration that no serious difficulty was experienced.

A glance at the table of temperatures will illustrate this fact—for instance, from the 25th to the 28th inclusive of January, 1881, was the coldest weather indicated for any four consecutive days in the five years. For the following twenty days the temperature averaged 33 degrees, one

TABLE No. 1.

Temperature in Fahrenheit at Dantzic.

	1		2		3		4		5		6		7		8		9		10		11		12		13		14		15		16	
	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.
1878–79.																																
Dec.	39	37	43	37	46	43	43	39	43	41	41	37	37	32	34	30	37	32	37	34	37	34	34	34	37	32	32	23	28	23	28	25
Jan.	48	32	37	32	37	30	37	30	32	30	32	25	30	19	32	25	28	14	25	14	28	21	30	28	32	30	32	28	32	28	30	28
Feb.	21	10	28	5	23	5	28	14	28	14	37	28	41	37	41	37	43	41	46	39	52	34	46	34	37	32	34	25	34	28	32	28
March.	37	30	37	28	37	32	39	32	39	34	43	37	43	37	43	39	48	39	46	39	43	23	37	28	34	23	32	25	34	25	34	28
1879–80.																																
Dec.	23	5	16	3	21	14	21	5	19	10	25	19	19	1	10	-2	23	5	25	14	34	25	34	28	37	30	34	30	41	34	39	37
Jan.	39	30	43	32	41	39	41	37	41	34	39	34	39	34	37	32	37	34	34	28	37	34	34	34	37	31	37	30	30	21	25	23
Feb.	32	12	34	14	41	28	41	30	37	25	34	30	37	28	37	28	37	25	37	28	37	28	37	28	34	28	34	32	34	28	30	25
March.	50	37	43	39	48	45	46	39	43	32	43	34	48	32	34	28	46	32	55	37	39	32	32	25	34	28	39	28	34	28	41	32
1880–81.																																
Dec.	43	41	43	32	34	30	32	25	37	28	28	25	41	28	43	39	46	32	39	32	41	39	43	37	37	34	37	30	30	25	32	25
Jan.	37	30	39	32	43	39	39	37	37	30	37	32	37	32	34	28	32	28	32	21	23	16	23	16	19	10	23	10	23	10	19	12
Feb.	41	30	37	32	34	32	34	32	37	30	37	30	39	21	37	25	41	34	39	32	41	28	30	25	34	21	32	30	34	30	37	32
March.	43	28	30	25	32	25	30	23	28	21	28	14	34	19	46	41	46	34	43	32	37	32	43	34	34	28	32	25	37	25	43	30
1881–82.																																
Dec.	48	37	39	37	37	28	32	30	34	30	34	32	34	32	32	32	39	32	34	28	32	30	37	32	32	30	34	30	30	21	46	21
Jan.	39	30	39	30	46	39	43	39	41	39	46	39	46	41	41	39	41	37	43	41	43	37	39	34	37	28	34	23	34	25	39	28
Feb.	39	32	39	28	34	30	39	34	39	37	41	32	32	30	30	30	43	30	39	34	37	34	34	25	41	30	50	39	46	32	46	32
March.	37	32	52	37	52	39	41	39	46	41	50	39	37	34	50	39	50	41	52	46	52	39	46	39	50	43	52	41	57	39	55	39
1882–83.																																
Dec.	21	16	19	14	14	10	16	10	25	16	30	25	32	28	34	28	34	32	30	23	34	30	34	30	32	30	34	32	32	30	34	30
Jan.	30	21	39	32	39	32	32	28	43	12	23	16	28	19	32	28	32	32	32	25	28	14	25	12	28	14	19	12	19	12	21	12
Feb.	34	28	37	30	43	30	39	32	34	30	30	25	28	25	25	23	23	21	30	21	34	23	43	28	34	23	34	28	30	19	25	14
March.	34	30	32	25	39	25	41	28	37	32	37	25	28	21	28	19	37	12	25	3	25	5	30	23	30	16	30	10	25	7	32	10

	17		18		19		20		21		22		23		24		25		26		27		28		29		30		31	
	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.
1878–79.																														
Dec.	39	25	30	25	30	23	37	30	32	28	32	30	32	28	34	25	32	25	30	23	37	30	39	37	41	32	41	32	46	41
Jan.	30	28	32	28	28	28	34	28	28	23	23	19	32	19	34	32	37	32	32	28	32	28	37	32	34	25	25	5	14	7
Feb.	30	28	37	30	37	28	34	21	39	25	39	32	39	32	41	34	37	24	37	34	37	34	37	32	..	..	..	..	..	..
March.	24	25	37	28	41	28	39	28	32	23	32	28	30	21	32	28	34	23	34	23	34	28	34	30	37	32	41	34	50	28
1879–80.																														
Dec.	39	34	37	32	37	32	37	28	32	19	37	19	39	37	39	32	39	32	37	32	37	19	32	19	43	37	41	34	39	34
Jan.	28	14	25	21	23	14	28	16	32	23	32	16	32	16	37	25	34	23	32	7	30	7	34	19	30	14	32	7	25	5
Feb.	28	7	16	10	37	10	46	37	46	37	37	30	37	25	32	25	34	25	39	32	39	30	39	32	43	32	..	..	..	..
March.	34	23	30	21	39	32	37	30	39	25	39	25	39	30	39	32	43	30	43	28	50	30	43	34	48	24	37	32	46	34
1880–81.																														
Dec.	32	14	34	10	39	34	37	24	41	32	37	30	39	25	41	34	43	34	39	37	37	32	37	32	41	34	41	39	41	32
Jan.	21	16	21	3	12	10	19	10	25	14	21	12	28	19	30	19	23	1	14	-4	10	-4	30	7	34	30	37	34	37	32
Feb.	37	32	32	16	23	16	25	16	30	21	32	16	32	19	39	19	39	19	37	30	32	16	28	16	..	..	..	..	..	..
March.	50	34	48	34	46	34	41	30	41	21	34	23	39	25	41	30	41	37	43	30	43	32	50	30	46	32	41	30	46	32
1881–82.																														
Dec.	32	23	39	32	41	34	37	32	37	32	37	32	37	28	32	28	32	28	39	32	43	41	43	34	41	37	43	34	37	34
Jan.	37	32	39	37	41	39	43	39	41	41	41	37	37	37	43	37	43	39	43	32	37	32	39	34	43	32	37	30	34	32
Feb.	41	32	43	34	43	32	41	32	43	25	43	25	48	34	48	41	43	39	57	43	57	48	52	32	..	..	..	..	..	..
March.	50	37	41	30	55	32	66	32	68	41	50	37	46	34	46	39	48	41	46	34	50	41	48	43	48	41	52	46	59	43
1882–83.																														
Dec.	30	21	21	14	21	14	..	..	25	19	28	25	28	25	30	25	32	21	32	23	30	19	43	21	41	25	43	30	30	25
Jan.	28	21	32	23	34	23	34	32	34	30	32	28	28	16	16	19	21	19	28	21	34	25	37	30	37	30	43	28	37	28
Feb.	28	14	32	16	28	14	28	12	39	23	46	34	39	32	39	30	39	34	34	28	37	30	41	32	..	..	..	..	..	..
March.	30	10	30	10	32	23	30	23	25	7	19	3	28	14	32	19	32	23	39	25	41	28	39	30	37	30	39	30	39	28

TABLE No. 2.

Temperature in Fahrenheit at Worcester.

	1 Max.	1 Min.	2 Max.	2 Min.	3 Max.	3 Min.	4 Max.	4 Min.	5 Max.	5 Min.	6 Max.	6 Min.	7 Max.	7 Min.	8 Max.	8 Min.	9 Max.	9 Min.	10 Max.	10 Min.
1878–79.																				
Dec.....	36	20	52	34	41	38	35	33	32	27	28	23	24	14	26	18	27	24	54	33
Jan	30	16	29	20	10	-1	20	12	23	16	20	12	20	6	32	22	33	28	27	11
Feb. ...	21	16	20	8	29	22	29	26	32	18	30	23	28	10	24	14	28	16	14	2
March..	30	12	33	24	32	22	38	23	40	26	26	8	30	25	31	6	34	26	44	32
1879–80.																				
Dec.....	40	16	46	28	52	36	48	36	39	26	40	32	48	42	42	40	34	28	41	28
Jan.....	30	10	40	34	28	22	44	36	38	28	32	22	36	28	36	20	32	30	40	32
Feb. ...	28	12	8	-10	28	8	22	14	22	8	22	18	30	8	22	3	28	4	22	-12
March..	34	30	32	14	46	24	52	44	54	42	36	32	38	24	32	22	20	10	34	22
1880–81.																				
Dec	28	20	25	16	22	14	28	16	34	22	34	30	26	18	16	4	18	10	12	8
Jan.....	6	-12	20	6	30	8	20	10	32	18	32	20	32	22	20	4	20	-2	32	30
Feb. ...	16	4	0	-10	8	-4	16	6	22	10	28	14	30	18	38	16	42	36	46	40
March..	40	36	32	24	34	32	36	32	32	24	34	30	42	24	38	24	36	32	38	36
1881–82.																				
Dec.....	56	46	37	28	38	30	34	30	37	28	39	24	42	38	32	24	40	28	27	12
Jan.....	28	22	10	8	18	-4	14	-4	16	-2	24	16	32	30	32	18	44	34	34	30
Feb. ...	28	18	32	20	28	12	12	-2	20	8	21	8	30	14	32	26	40	20	32	28
March..	48	30	44	42	44	36	38	32	46	30	42	36	30	28	30	12	32	20	44	34
1882–83.																				
Dec.....	30	20	40	30	18	10	18	-2	38	28	44	35	38	11	14	10	18	10	30	20
Jan.....	24	10	30	18	30	2	18	10	10	0	10	2	26	10	26	13	22	10	9	4
Feb. ...	24	14	20	6	24	16	42	26	25	16	22	4	34	24	23	10	28	16	11	0
March..	30	10	46	34	30	18	20	2	8	-4	20	-2	20	10	10	-8	20	-4	38	20

	11 Max.	11 Min.	12 Max.	12 Min.	13 Max.	13 Min.	14 Max.	14 Min.	15 Max.	15 Min.	16 Max.	16 Min.	17 Max.	17 Min.	18 Max.	18 Min.	19 Max.	19 Min.	20 Max.	20 Min.
1878–79.																				
Dec.....	38	34	34	30	32	28	30	21	33	30	26	20	24	11	28	20	26	20	28	17
Jan	22	10	25	8	32	22	34	20	8	3	12	2	28	5	32	10	25	10	19	8
Feb. ...	42	30	42	30	24	20	14	6	12	0	26	6	35	20	22	18	18	5	22	14
March..	50	38	35	27	39	32	42	30	32	27	32	17	32	22	25	17	32	10	34	20
1879–80.																				
Dec.....	56	38	32	24	30	18	32	26	36	30	31	26	34	28	14	1	30	22	32	22
Jan.....	38	32	46	34	22	12	22	4	38	24	37	26	44	30	36	30	38	32	32	30
Feb. ...	31	8	43	36	44	42	42	30	32	26	32	23	44	30	55	40	28	18	20	10
March..	20	14	28	20	30	13	32	22	40	22	32	26	32	30	30	14	32	26	39	24
1880–81.																				
Dec	20	10	28	14	40	26	34	28	34	33	32	22	20	10	20	10	28	10	32	16
Jan.....	24	18	18	12	34	18	36	28	10	-2	28	16	30	24	24	10	32	18	25	20
Feb. ...	46	34	34	30	32	28	20	14	26	10	42	20	30	16	30	18	34	28	30	16
March..	30	24	38	22	40	30	40	30	40	30	40	30	40	30	40	30	44	30	34	32
1881–82.																				
Dec.....	22	6	34	18	50	38	58	46	32	18	18	4	30	20	40	30	38	24	37	34
Jan.....	32	22	34	20	30	18	30	20	28	20	38	30	20	4	20	-8	30	26	30	10
Feb. ...	22	16	36	24	44	32	38	32	43	30	50	30	44	24	14	0	22	10	36	26
March..	36	26	38	28	35	29	24	16	28	12	32	22	32	22	30	18	40	28	48	30
1882–83.																				
Dec.....	28	24	20	10	34	14	24	22	22	14	14	10	22	10	24	12	18	8	22	14
Jan.....	12	4	8	2	32	6	36	20	20	4	26	6	28	8	30	26	29	8	30	18
Feb. ...	31	10	27	16	28	8	30	17	26	16	38	24	48	36	24	18	30	14	30	6
March..	30	16	24	0	30	22	36	10	40	28	16	10	32	10	48	30	39	28	34	20

	21 Max.	21 Min.	22 Max.	22 Min.	23 Max.	23 Min.	24 Max.	24 Min.	25 Max.	25 Min.	26 Max.	26 Min.	27 Max.	27 Min.	28 Max.	28 Min.	29 Max.	29 Min.	30 Max.	30 Min.	31 Max.	31 Min.
1878–79.																						
Dec.....	25	18	34	30	24	16	15	12	21	11	22	14	29	20	23	20	22	11	24	18	24	10
Jan	12	-3	32	26	34	26	30	18	38	26	8	2	31	6	44	36	30	20	24	10	30	16
Feb. ...	13	10	19	2	35	16	14	10	25	6	44	20	18	12	11	0	..	..	..	..	..	..
March..	34	28	38	17	33	30	38	20	36	34	42	26	32	32	34	30	49	30	48	32	31	23
1879–80.																						
Dec.....	2	0	14	0	28	20	34	30	34	22	10	-5	46	8	34	22	40	30	40	24	8	4
Jan.....	24	18	26	6	38	36	32	18	10	16	42	26	38	32	48	36	26	12	34	10	40	28
Feb. ...	32	20	32	20	34	30	24	10	40	24	44	36	48	34	52	30	54	46	..	..	..	..
March..	38	28	44	24	40	30	32	20	24	12	34	18	33	24	30	30	38	24	35	28	41	24
1880–81.																						
Dec	26	24	32	20	30	16	30	26	28	26	32	26	32	24	18	10	12	8	-2	-10	..	..
Jan.....	28	18	22	14	16	4	18	6	20	8	12	8	6	0	8	0	18	4	12	6	14	4
Feb. ...	31	22	30	14	35	20	4	-6	16	0	18	0	40	32	46	40	..	..	..	..	..	..
March..	36	30	38	30	34	24	36	24	36	26	30	24	30	22	34	24	36	24	32	30	30	28
1881–82.																						
Dec.....	38	30	48	34	50	30	20	12	35	20	44	34	48	42	42	38	46	40	36	32	30	26
Jan.....	35	28	32	10	0	-6	-6	-18	22	0	38	35	40	32	30	20	22	10	20	8	30	10
Feb. ...	30	20	30	18	20	6	28	8	30	10	34	16	38	32	44	30	..	..	..	..	..	..
March..	30	30	40	24	32	20	32	24	22	10	32	18	48	38	38	34	38	22	40	33	28	22
1882–83.																						
Dec.....	32	22	32	28	33	22	32	28	33	28	30	22	32	20	24	18	24	10	30	13	32	20
Jan.....	38	18	8	2	-1	-8	16	-4	20	16	18	6	32	18	36	32	32	26	32	25	36	32
Feb. ...	20	16	30	16	24	12	30	6	42	30	27	20	12	4	24	17	..	..	..	..	..	..
March..	26	11	20	8	28	10	29	10	36	18	44	28	36	33	35	28	32	18	36	24	36	18

degree above the freezing point, so that whatever frost had penetrated the ground during the short cold period would undoubtedly be removed long before the twenty days expired. In fact there could have been very little severe frost after this time, for the average temperature of the month of February following was 28 degrees Fahr., while March had an average of 34 degrees Fahr.

It is true that here in New England extremes of cold are followed frequently by warmer periods, that is, the weather is not excessively cold for long periods of time, but the reaction is not generally great, and it is almost too well known a fact to be commented upon, that after the frost once enters the ground here, it stays with almost constantly increasing depth until spring fairly opens.

That this difference in climatic conditions is likely to prove a troublesome matter, if any method of land treatment is exclusively relied upon, there would seem to be but little doubt.

Whether the excessive cold of our New England winters would prove to be an insurmountable obstacle to this method of sewage disposal, can only be determined by experiments extending over a series of years. The fact that there may be some difficulty has been recognized in reports made upon the subject by experts employed by the State.

The Commission appointed by the State Board of Health in 1881, consisting of Charles F. Folsom, M.D., Joseph P. Davis, M. Am. Soc. C. E., and Henry P. Walcott, M.D., after carefully investigating the subject, say in their report to the Board:

"Considering the extreme heat and cold of the climate, the heavy rainfall, and the great dilution of the sewage, the difficulties in the way of a satisfactory disposal of the sewage of Worcester are far beyond those of any other town where the question has been met, so that any scheme that may be proposed may be said to be experimental to a certain extent, and to be successful, and not create a greater nuisance than it abolishes, it must be costly in the original outlay and involve also a considerable yearly expense."

Mr. Eliot C. Clarke, M. Am. Soc. C. E., in his report to the Commission appointed by the Governor under an Act of the Legislature, in 1884, says on page 133, after discussing the different methods employed abroad for sewage purification:

"Almost all the examples of sewage treatment on which the foregoing statements are based occur in England. The conditions, climatic and other, existing in Massachusetts are somewhat different from those in England. How far this difference of conditions might affect the choice of methods of disposal here, can only be definitely learned by experiment."

It would certainly seem from the above statements that the persons making the reports referred to had some doubt as to the successful working of any scheme of land purification, although they recommended downward intermittent filtration.

The sewage farm at Pullman, Ill., has frequently been cited as being a place where successful purification of sewage is accomplished in the winter, in a climate similar to that of New England.

In order to fully satisfy myself as to the fact, I visited Pullman in January of the present year.

The farm has an area of about one hundred and forty acres, nearly all of which is devoted to irrigation; there are ten acres, however, set apart for a filtration area, this being thoroughly underdrained, the drains being about twelve feet apart.

Upon the day of my visit it was quite warm, the thermometer registering forty degrees Fahr. I found that the sewage was all being discharged upon the filtration area, the first section of which was covered with sludge to a depth of about a foot. The sewage was running over this, to the second section which was partially covered with ice, and then over the remaining area which was entirely covered with ice, and was finally discharged into the effluent trench without having been filtered in the least.

I was told that not a particle of sewage has been applied to the farm proper during the winter, it all having been simply passed over the area as already described.

Mr. B. S. Brundell, C. E., M. Inst. C. E., one of the ablest sanitary engineers in England, and a gentleman who has constructed many sewage farms, among the number, the farm at Doncaster, which is one of the most successful farms in operation (from a sanitary point of view) in England, says in a letter to me on the subject:

> "Our winters here, although adding to the trouble of sewage irrigation, do not make it impossible. The temperature of the sewage, when it reaches the land is sufficiently high to keep the outfalls open; but of course when it spreads upon the land it soon becomes frozen, and remains a glazed surface until the thaw sets in when it is gradually absorbed by the land.
>
> "I do not feel able to give an opinion as to how far this process would be limited by the degree of cold to which you are liable, but I foresee very considerable difficulty in the matter."

Mr. James Mansergh, C. E., M. Inst. C. E., in answer to a similar inquiry, says:

"I have carefully considered, in the light of my experience in England, whether under such conditions as these, the disposal of sewage by way of broad irrigation and downward intermittent filtration may be counted on as a reliable and satisfactory mode of treatment. I have heard that, in the severe winters we have had here since 1878, it has been with some difficulty that trouble has been avoided on more than one farm.

"Under the conditions you have described to me, I should have very great hesitation in recommending the process of broad irrigation and intermittent filtration as reliable modes of disposing of the sewage and preventing the pollution of the river.

"I should fear that during such frosts, as you tell me not unfrequently prevail, the ground would get frozen so hard as to render it impervious to the sewage which would then simply flow over the surface into the river or its tributaries in a crude condition.

"In order to acquaint myself more particularly with the relative temperatures at Worcester, U. S., and England, I have obtained certain statistics from Mr. G. W. Symonds, F. R. S., which I have embodied in the accompanying diagram."

I will not show Mr. Mansergh's diagram here, but will simply say that it shows the difference in temperature between Massachusetts, England, and Germany, the figures corresponding very closely with those given above. In conclusion he says:

"All these figures confirm me in my opinion that it would not be prudent to trust to getting rid of sewage satisfactorily at Worcester by the irrigation process."

The great difference in the amount of annual rainfall is also an important factor to be considered. The greatest rainfall given at any place visited was at Wigan, where the average is about forty inches per annum, while the smallest amount was at Barnsley, where the average was given as $28\frac{6}{10}$ inches per annum. The average of all places visited was 34 inches per annum.

At Worcester the average is about forty-eight inches per annum, the lowest recorded amount for one year being 34.5 inches, or about the same as the average amount at the places where inquiry was made, while the greatest recorded rainfall for one year at Worcester is 61.48 inches.

Now it is generally the experience abroad that during storms the sewage has to be disposed of in some other way than by irrigation, the ground being frequently surcharged with water, rendering it incapable of purifying the sewage at all. With the large rainfall here, this difficulty would be very much increased.

Aside from the difficulties caused by climatic differences, there is still another objection to irrigation in the case of a city or town

situated as Worcester is, at the head of a large manufacturing stream, where every drop of water running in the river is utilized for power. I refer to the loss of water by this means of sewage disposal. Just what the amount would be that the vegetation would absorb, and that would evaporate, can only be determined by actual trial.

At Berlin, the experiments show that at least 30 per cent. is retained, while at Doncaster most of the water is lost in this way, the reason being that only a small quantity of sewage is applied to any one piece of land, the intention being not to apply more than would come in an ordinary rainfall. That the loss of water would be considerable, there can be no doubt.

The above are the principal objections to irrigation so far as localities similar to central Massachusetts are concerned. While they are more or less local in their character, there is danger that by the adoption of irrigation, especially when a large quantity of sewage is to be treated, the irrigation fields will become a greater nuisance than the one which is to be abated. In other words, it takes the most careful management to prevent a sewage farm from becoming offensive.

My own observation was, that at about one-half the places visited, more or less odor was noticeable. The weather was quite favorable, however, it being in the fall.

The great danger here would be with the greater amount of heat in the summer, and great care would have to be exercised to prevent more sewage being applied to the land than would be readily absorbed.

That this trouble is recognized in England, the report of the Royal Commission on Metropolitan Sewage Discharge, for 1884, will show.

I will not attempt to quote from that report here, but there is abundant testimony that the irrigation fields, especially when they are located near dwellings, are at times very offensive.

What has been said in relation to treating sewage by irrigation, applies also to downward intermittent filtration, so far as the effect of the climatic and other conditions are concerned; in some respects, however, not to so great an extent; for instance, the amount of water lost by evaporation and absorption would not be as great, the effect of severe frosts would probably be about the same, as in order to obtain an effluent that is at all satisfactory the application (as the name of the system implies) must be intermittent; it will not do to simply turn the sewage constantly over a single area of underdrained land and expect

that a clear effluent will be obtained; the land must have rest. "The intermittency is a *sine qua non* even in suitably constituted soils, whenever complete success is aimed at." The danger would be that after one filtration area has received all the sewage that can be applied at one time, and before the relatively warm sewage can be again applied (generally after three or four days), the ground would be frozen to such an extent that filtration would not take place.

The temperature of the sewage has therefore much to do with the length of time that the ground can be kept open, and also with the extent of the area upon which sewage can be applied in cold weather. There were only two places that I visited where a record had been kept of the temperature of the sewage, viz., at Berlin and Paris. At the former place the lowest temperature reached in winter was 45 degrees Fahr., while at the latter place the minimum was 41 degrees Fahr. At Pullman there has been no record kept, so I was told, but the sewage must be very warm, as the "separate system" of sewers is in use, and nothing but house drainage is allowed to enter the sewers, all surface water being excluded.

At Worcester the sewers have all been constructed to receive drainage of every nature. All surface water is conducted to them, and in consequence the temperature of the sewage is at times very low. The record shows that in the main lateral sewers as low as 33 degrees Fahr. is reached. It is probable therefore that sewage taken from them and applied to the land would freeze quickly and could not be depended upon to keep the ground free from frost.

The advantage that intermittent filtration would have over broad irrigation, is that a much smaller area of land would be required, and the raising of crops would have to be made of secondary importance. In fact it would be much better not to attempt to raise crops at all, as the income derived therefrom would be small, and the tendency would probably be to neglect the purification of the sewage in order to derive as large an income as possible from the land.

It must be understood that in order to obtain a good effluent, especially when the area of land is limited, some means of separating the sludge from the sewage is almost absolutely necessary to prevent the ground from clogging. This fact is recognized by English authorities and, as before shown, this method of sewage treatment has been rarely used except as an auxiliary to irrigation or precipitation.

Chemical precipitation would not be subject to the objections spoken of above, and where the sewage has to be treated constantly, through the entire year, would seem to be a method that presents many advantages. Much depends, however, upon the conditions that exist in different localities. No fixed rule can be laid down as the only one to be followed, but the solution of the method to be used, must be determined, it seems to me, only after a most careful and conscientious study of existing circumstances. For the City of Worcester I have recommended chemical precipitation, with the possible addition of a filtration area, to be used in connection with the precipitation works during the summer months.

DISCUSSION ON SEWAGE DISPOSAL.

Eliot C. Clarke, M. Am. Soc. C. E.—I fear I cannot add much to what has been presented; but as the sewage-disposal works at Medfield, designed by me, have been referred to, I will give a brief description of them. The state of things which called for some remedy was this: Medfield is a country village with a single large factory where straw braid is sewed, dyed and shaped into hats and bonnets. Through the village flows a brook into which the factory and also some of the houses drained. This brook was thus rendered very foul and offensive. The greater part of the pollution was due to the factory drainage, which, roughly estimated, amounted to 36 000 gallons a day. Abutters on the lower part of the brook made frequent complaints, and threatened suits and injunctions. It was feared that the factory would be closed or be driven from the town. The problem was: to dispose of the factory sewage without causing any nuisance and without polluting Charles River, in whose watershed Medfield lies, this river being used below as a source of domestic water supply. What was done was this: A drain was built, extending from the factory, about a mile, to a tract of gravelly soil on the outskirts of the village, where a square acre was prepared as a filter bed, and the sewage disposed of upon it by intermittent filtration.

A Member.—How large was the population?

Mr. E. C. Clarke.—Five hundred operatives are employed in the factory, and the water closets used by them connect with the sewer. About half a dozen houses also are at present connected. Medfield has no other sewers; but when any are built, this one can be used as an outlet for them. Then the filter beds may need to be enlarged. At present the chief source of pollution in the sewage is manufacturing refuse from the factory. Some of this refuse, as, for instance, the ground dye woods, might have caused trouble by settling in the sewer and clogging it. To prevent this, such matters are arrested by subsidence and filtration at the factory, before the waste water containing them is admitted to the sewer. This is done by causing the sewage to flow first through a large tank, divided into several compartments by bridge walls, over which the sewage flows. In these compartments much of the bark settles. In the last compartment is a large mattress of excelsior through which the sewage is made to filter upwards, by which all but the finest particles are intercepted.

Still the sewage is very dark colored and foul looking when it reaches the filtration area. This area is nearly square, an acre in extent, and is divided by two low banks bisecting it at right angles to each other, into four square quarters of an acre. The sewer ends at the middle of the large area and its outlet is so arranged that the sewage can be turned upon any one of the four quarter-acre plots. It has been the practice to let the sewage run for two days upon one plot, then change it for two

days to the next plot, and so on to each in rotation. Thus each plot receives the sewage for two days and rests for six days before receiving its next dose.

The works were completed and filtration began in November, 1886, just before the advent of freezing weather. As is usual in such cases, the selectmen and other inhabitants of the town predicted dire results as sure to be caused by the effect of frost on the sewage and the filter beds. The first winter was a cold one; 13 degrees below zero Fahr. was noted one day at the filtration area, but there was no trouble on that account. A thin sheet of ice formed, but the sewage flowing beneath it thawed the ground and filtered through it.

This area is not underdrained. It was important to avoid all unnecessary expense, and as the soil was very porous and the ground water low, I thought drains could be dispensed with, as proved to be the fact. Consequently, the immediate effluent from the filter beds cannot be seen. It appears, however, a short distance away. The filter beds were graded on sloping land, and at the bottom of the slope, a few hundred feet from the beds, is a flowing spring which undoubtedly receives all of the filtered sewage. The flow from the spring has about doubled since the works went into operation, and the water is just as limpid and tastes as well as it did before. No one drinking it would suspect that it was not good clean spring water.

I wish we might rid ourselves of this bugbear of the injurious effect of frost upon sewage disposal. The Pullman works are instructive on this point. There 800 000 gallons of sewage a day are disposed of, and in the winter it is turned upon two or three acres of filter beds which are used for months at a time Of course that is too long a period to produce good results and the surface of the ground becomes clogged by sediment; but the ground does not freeze. I once visited the Pullman works in winter when the weather had been very cold. For about a week the mercury had been below zero. It had been as low as twenty degrees below, and on the day of my visit registered twelve below. The ice on the surface of the sewage, in places, was 10 inches thick. I cut a hole through it and found the ground beneath perfectly open. The sewage was filtering through the ground without regard to the frost. There was too much sewage for the area of land used and the effluent was quite dirty. The soil at the Pullman farm is not suitable for purifying large quantities of sewage. From my own experience: given good, porous, gravelly land, such as we had at Medfield, I would not be afraid to apply 100 000 gallons of ordinary sewage to each acre throughout the year. There would be no danger of the soil clogging in time. At Medfield, as at other filtration areas I have seen, the solid particles in the sewage form a thin deposit, entirely upon the surface of the ground. They do not penetrate it at all. By leaving the land unused for a few days this thin scum of deposit dries, cracks and curls up in detached

pieces. When too much of it has accumulated, it can be raked off of the surface of the ground.

I have visited from twenty to thirty sewage-disposal works in England and I thought that the most successful ones were those which practiced intermittent filtration. When this method was not successful it seemed to be due to the fact that the primary object, *i. e.*, the purification of the sewage, was interfered with by an attempt to make money by cultivating the filtration areas.

L. B. WARD, M. Am. Soc. C. E.—I would like to ask what were the results of your observation in regard to the sense of smell?

Mr. E. C. CLARKE.—At well-managed sewage farms there was little, if any, smell. Some of the English farms are very large, and the farmers and laborers, with their families, live in cottages surrounded by the irrigated fields. Neither adults nor children seem to suffer thereby. I noticed the children especially, and they looked as sturdy as any that I saw elsewhere. On muggy days, when the air is heavy, and everything which can give out a smell does so, a slight odor will be noticed at even a well-managed farm. But it is not a strong nor an offensive odor and people do not seem to mind it. The Vice-President of the Pullman Company lives contentedly in a very handsome house within a few hundred feet of the sewage farm. Mr. Martin, the Superintendent of the farm, with his family, lives in a nice house situated near to the center of the farm. He says that he is not troubled by any offensive odors. There is a village growing up on land contiguous to the farm. Certainly people would not settle there and build houses if they were exposed to bad smells. The fact is, that fresh sewage applied promptly to land in a thin sheet does not give off any bad smell; but if it is permitted to stand stagnant in a ditch or pool until it putrifies, it becomes offensive. Ditches therefore are to be avoided in connection with land purification. It is better practice to draw the sewage upon the land from hydrants or from smooth channels, elevated above the general surface of the ground. With such precautions and with soil of suitable character, sewage filtration can be carried on without risk of causing any nuisance.

A MEMBER.—What is the depth of the sewage on the Medfield quarter of an acre filter beds? What is the depth of the sewage deposited on them?

Mr. E. C. CLARKE.—It cannot be said that there is any depth to the sewage, because no one of the quarter-acre plots has ever been entirely covered. That is, the sewage sinks into the ground before reaching the farther side of the plot. The farthest point ever reached by the sewage in flowing, before it sinks into the ground, is readily determined, because the sewage is full of dye stuffs and discolors the gravel surfaces of the beds wherever it reaches them. Roughly speaking, about one-half of each bed shows such discoloration, or did so the last time I saw them.

A MEMBER.—Do you remember the depth of the gravel bed?

MR. E. C. CLARKE.—It is a natural gravel formation and I do not know its depth. I had a pit dug from eight to ten feet deep to determine the elevation of the ground water. To that depth the character of soil was uniform, consisting of pebbles of various sizes, the interstices being filled with coarse sand. If the soil water had been less than eight feet below the surface under-drainage might have been necessary.

A MEMBER.—It has a sloping surface?

MR. E. C. CLARKE.—The land was inclined, but we graded it to a nearly level plane. We made the center of the large area, where the sewer outlet is, a little the highest, so as to cause the sewage to flow over the beds. The inclination downwards from the point where the sewage enters a bed is about six inches in a hundred feet.

J. S. SCHAEFFER, M. Am. Soc. C. E.—There are many systems where you admit all the drainage water directly into the sewers?

MR. E. C. CLARKE.—You cannot have a perfect system of purification where you admit surface water into the sewers. Of course, during dry seasons such a system will work as well as any other, there being nothing but the ordinary sewage proper to be disposed of. But when the sewers are flowing full with rain water, the amount of sewage will be too great to be adequately treated in any way. At such times the greater part of it must overflow into the water-courses. It will be so dilute that usually no nuisance will be caused by such occasional overflow and if it is only necessary to avoid causing a nuisance such a system will be proper. But when there are legal restrictions or other reasons against discharging *any* sewage without purification, this can only be accomplished by building a separate system of sewerage.

MR. SCHAEFFER.—I would like to ask whether the water has been chemically analyzed?

MR. E. C. CLARKE.—The State Board of Health made an analysis, but I have not seen the result. I understand that it showed marked evidence of previous sewage contamination, but also showed that all organic matters had been changed into harmless products, and that the water was entirely potable.

MR. WARD.—Where this sewage is used on the farms, what is your information in regard to the quality of the vegetables?

MR. E. C. CLARKE.—I only know what I have been told. At the market gardens, near Paris, which are irrigated with sewage, they said that the vegetables were greatly improved, and were in much request at the clubs. Mr. Martin, the Superintendent of the Pullman farm, tells me that he gets the finest celery to be found anywhere. It may well be so. There are farms in the vicinity of Boston devoted to raising garden truck where during certain seasons of the year, water for irrigation is purchased at the rate of two cents per one hundred gallons, and is used at the rate of 500 000 gallons a day. For this purpose sewage, unless it contained too

much manufacturing refuse ought to be worth as much as pure water, or a little more. At the Pullman farm, sewage is only applied to such vegetables as will be benefited by it. Potatoes never receive any of it. This farm is said to clear a profit of $5 000 a year, which does not seem to be very much for a farm of its size. Still Mr. Martin thinks that having the sewage water to use whenever it is needed, is of great advantage to him. I understand that loamy and clayey soils are somewhat more benefited by the application of sewage than are sandy soils. Perhaps this is because they are more rich in humic acids which fix and retain the ammonia contained by the sewage. A clay soil, however, can dispose of so little sewage that it is necessary to use a very much larger area of it.

A Member.—How much?

Mr. E. C. Clarke.—It depends entirely upon the character of the soil. I cannot say exactly; at least ten times as much.

F. P. Stearns, M. Am. Soc. C. E.—There is one point which I think deserves consideration in connection with the question of the winter disposal of sewage upon land, and this is the temperature of the sewage. This, in many cases, depends chiefly upon the temperature of the water supply.

In Boston the water drawn from the pipes in winter has a temperature of 37 degrees, and the sewage as it enters the reservoir of the main drainage works is at 43 degrees. Late in the autumn or early in the spring when the water is somewhat warmer, the sewage is also warmer by about the same amount.

Water taken from Massachusetts rivers, when covered with ice, is very near the freezing point; while, on the other hand, water drawn from a well or other ground-water source has, even in winter, a temperature of about fifty degrees.

In the coldest weather in winter I have observed the temperature of sewage discharged upon a disposal area at one public institution to be 41 degrees, at another 51 degrees, while in another instance in which the water supply comes from the ground and the sewage is warmed to a considerable extent by the discharge of hot water from a factory, the temperature is as high as 60 degrees.

While it is probable that the coldest sewage may be disposed of upon land in winter in this climate, such disposal may be more confidently advised where the sewage is warmer, and in seeking for precedents it is desirable to know the temperature of the sewage as well as the severity of the winters.

Robert Moore, M. Am. Soc. C. E.—I think, Mr. President, this trouble which Mr. Allen speaks of, of danger of failure from cold weather, if it were a real one, would occur in the winter. In very cold weather, when the windows are closed there would be no incon-

venience caused by it. If the sewage were turned into the streams so that no decomposition takes place, the conditions which would cause a nuisance would be absent. I think, at Pullman, there is no trouble at all in the winter. The sewage itself is of a comparatively inoffensive character, but the whole process is conducted so carelessly that if any trouble would arise anywhere it would arise there.

Emil Kuichling, M. Am. Soc. C. E.—It is a matter of some importance in this discussion to draw a line of distinction between the uses to which the effluent is put. It has been found, I think, by recent investigations in England and elsewhere, that the filtration of sewage through gravel is simply a mechanical separation or removal of the particles held in suspension, and that no appreciable portion of the matter in solution is removed thereby; hence, if the effluent is to be admitted into a stream from which water is to be taken for drinking purposes, the quality of the effluent is a thing to be very carefully considered. This is to-day, a matter of very serious consideration, even in places where the filtration takes place through fine sand, or sandy loam. Perhaps the most extensive recent investigations of this kind are those conducted by Professor Alexander Müller, of Berlin, who was connected with the sewage commission of that city, and the investigations made by him led to the conclusion that the subsoil water might become seriously polluted by the percolation from a sewage farm. In 1885 Professor Müller submitted a report to the German Agricultural Council, in which serious attacks were made on the quality of the effluents from the Berlin sewage farms, a portion of which goes into the River Spree, above the water-works' intake. In this investigation it was found that a contamination of the subsoil water had actually taken place. The soil on these farms and vicinity, for miles in extent, is a fine sandy loam of indefinite depth.

Professor Müller states that when such lands are heavily irrigated, the amount of organic matter conveyed by the sewage may easily reach a limit which threatens not only the existence of the food-plants growing upon the surface, but also that of the nitrifying ferments or organisms contained in the soil. Under these conditions, the tendency is to bring about a slow putrefaction of the organic substances, with the development of products of a more or less noxious character, instead of the desirable rapid decomposition or nitrification. The excess of soluble organic matter must accordingly pass into the ground water, where it serves as nutriment for a different class of microbes, whose presence or development may perhaps be very undesirable when such water is used for drinking purposes. Some of these products of putrefaction are, moreover, known to be active poisons, and should therefore be excluded as far as possible from subterranean water supplies. Difficulties of this kind are liable to occur when large volumes of sewage are fil-

tered through very porous soils of considerable depth, and the pollution of the subsoil water has been traced for long distances beyond the boundaries of the filtration area. Care should accordingly be taken to locate the sewage irrigation fields in places where it can be reasonably well demonstrated that the ground water soon finds its way into a natural stream, where the process of nitrification of the dissolved organic matter can be completed after a run of a number of miles, freely exposed to the action of the atmosphere.

Now, in discussing the subject of sewage disposal by irrigation or filtration, the important point to be borne in mind is the amount of liquid to be dealt with. From this only can the reduction to number of persons per acre per year be made. The estimates found in professional literature, however, are usually given in the latter form, and are therefore very often misleading, inasmuch as they always refer to rates of water consumption which are much less than what we find to be the case in American cities. The use of water in English and European cities ranges from 30 to 60 gallons per head per day, while we have here a consumption of from 60 to 150 gallons, of which a large proportion is waste; but everything is sewage which issues from the sewers, and therefore, in the consideration of sewage-disposal projects for our cities, the area required for irrigation or filtration must be correspondingly increased above the estimates based upon the foreign rates of water supply. The recognition of the influence of variability of the use or waste of water in different places has latterly led to the introduction of a new and better standard for estimating the required area of land, and which is based upon the weight or volume of sewage that can be thrown upon an acre of land per day or per year. If I remember right, the evidence given recently before the investigating commission on the discharge of the sewage of London indicated that for securing a good effluent from a sewage farm, we should not have more than about 1 500 tons of water or liquid per acre per year. This means about 1 100 United States gallons per acre per day; and if we reduce this to the other usual standard, we see that with a water supply or sewage production of 100 gallons per head per day, one acre of land will be required for the sewage of only eleven persons. The usual estimate found in manuals and reports is, however, that in broad irrigation one acre of land can take care of the sewage of from one hundred to two hundred persons without causing nuisance; and if this were to be applied with the sewage of our cities, we should have a weight of from 13 570 to 27 140 tons of liquid per acre per year. But for agricultural utilization of sewage on sandy soils, English authorities recommend that a maximum of from 5 000 to 10 000 tons should not be exceeded; hence it follows that for American conditions, we must estimate that the area of land required for broad irrigation is two or three times more than what is required abroad.

Sanitarians, on the other hand, demand a large reduction of the quantity of sewage allowed to flow upon land, holding that about three hundred tons per acre per year, or about 230 gallons per acre per day, should not be exceeded in order to comply with the two important sanitary conditions, namely: freedom from stench nuisance, and the avoidance of subsoil-water pollution. Where the slightest trouble from the failure to meet these conditions occurs, bitter attacks upon the farm and its management have invariably followed. Especially was this the case in Berlin, where they commenced the sewage irrigation on a basis of two hundred and fifty persons per acre, reducing year by year to two hundred, one hundred and twenty and one hundred persons per acre, in proportion as the acquired lands were adapted to irrigation. In the spring of 1884, I visited the two large sewage farms, measured by thousands of acres, which are owned by the City of Berlin. The director of the farms, a highly cultivated gentleman, stated that the tendency was to still further reduce the amount of sewage put upon land; he hoped to get it down to a basis of seventy-five persons per acre per year; but preferred to reduce it to fifty, but could not try it just then. By such a reduction they hoped to make a slight profit; also, "*sub rosa*," to do away with the alleged pollution of the subsoil waters and effect the abatement of the stench nuisance that occurs on all sewage farms and at pretty much all seasons of the year. During the winter and spring of 1883–84, I visited over thirty different sewage farms in Europe. The season was unusually mild, and nowhere was there any snow on the ground; but on all of these farms there was a marked odor which many would pronounce offensive.

Now, a question arises here which we are bound to take into consideration, in view of the unsettled condition of our laws relating to health, and that is: what punishment is a municipal corporation likely to suffer by creating a nuisance upon a sewage farm or sewage purification works? It is pretty well known to engineers that in all questions relating to interference with streams the only safe rule is "Hands off," that is to say, do not tamper with them in any way. We have perhaps an illustration of this doctrine in the case of the City of Rochester, where, at the present time, about one hundred and fifty suits for damages are pending, by reason of the pollution of several small natural water-courses through the discharge of raw sewage, and where almost every suit results in a verdict for the plaintiff. In this litigation the policy of the City of Rochester is simply to gain time by carrying these suits to the Court of Appeals. For years the construction of a suitable intercepting sewer has been agitated, but hitherto the fact has been that the interest on the cost of such a large sewer was much more than the damage which the juries have awarded to the farmers. The tendency of the juries is now, however, to gradually raise the amount of damages, and the time will soon come when the annual sums thus

awarded will exceed the interest on the cost of the contemplated sewer, whereupon its construction will doubtless be commenced. As a matter of fact, only a small amount of nuisance is occasioned in the most of these water-courses; but if the relatively slight nuisance resulting from the pollution of a little brook flowing through a farm is valued by our courts at appreciable sums every year, we may well be apprehensive of the results that would probably follow in the case of a badly planned or improperly managed large sewage farm or precipitating works.

At the great Berlin farms the sewage can at times not only be smelled at the distance of nearly half a mile, but it can also be tasted in the atmosphere. The same condition of things was likewise observed at a number of English farms. If we take into account all the complications resulting from the unsettled condition of our health laws and from the changes involved by our political system, I presume that the best method of treating sewage on a large scale is by some chemical process, combined with a filtration of the clarified effluent either through natural or artificial filters; and then, if the effluent is to be turned into a stream whose water is used for drinking purposes, there is less danger of infection.

A matter of considerable importance in this chemical treatment is the rate at which the sewage flows through the tanks. The most consistent of all the statements that I have found after considerable study of the subject is that given by Dr. Tidy, in which he states that two tanks should be used, the first one of such capacity as to receive at least one hour's discharge of sewage, while the second should hold at least four hours' flow after having passed through the first tank. From this formula the actual size of the tanks can be determined, it having been found by experience that the depth of the water therein should be from 5 to 6 feet. The general practice in England is to make the tanks with sloping bottom, the average depth being about 6 feet. With small tanks a more frequent removal of the sludge becomes necessary. The rate of flow through a series of tanks worked continuously is always quite small. With regard to discharging the effluent, it flows in a thin sheet over a long weir, and wherever possible, it is allowed to fall in a series of small cascades. The thickness of the sheet of liquid is generally about one-half an inch, and I can say from what I have seen of some of these chemical processes that the effluent is very good. Particularly is this true of the "A B C Process" at Aylesbury in England.

In regard to the matter of fish living in water polluted by organic matter, I was informed recently by a well-known pisciculturist that, for most varieties of fish, purity of the water is not so much an essential factor as freedom from suspended matter and temperature; that even the brook trout, which is popularly supposed to be a fish that can live only in the purest water, is in reality not a very delicate or fastidious animal, inasmuch as it can endure considerable occasional roiliness and pollution

of water by organic matter of both animal and vegetable origin ; but that on the other hand the brook trout must have a low temperature, which is the more important condition for its existence. I asked the gentleman to make some experiments on this subject with both raw and clarified sewage, but thus far he has not had the opportunity to do so, and hence no definite conclusions can be given. The effect of certain gases, salts and acids upon fish has, however, been carefully studied by Professor C. Weigelt, who has published the results arrived at in the "Archiv für Hygiene" for 1885.

It is therefore a popular fallacy that water in which brook trout will live is necessarily pure and fit for human consumption, since in many instances this is not the fact. The same is also true of the various forms of plant life. It does not follow, because certain plants, such as water-cress, grow in a stream of running water, that such water is pure ; the element of temperature, and the amount and kind of mineral matter in the water, both play an important rôle.

In regard to the aeration of the soil and the intermittence of the application of sewage, the observations that I have made in examining sewage farms agree with those of Mr. Allen. The surface of the land becomes to some extent clogged with matter of various kinds, forming a slimy coating which must be occasionally broken up by suitable cultivation. This is true both of broad irrigation and filtration wherever unsedimented sewage is applied. To insure a penetration of the liquid into the soil, the surface must either be worked, or else be given time to effect the destruction of the intercepted matter by natural processes, and hence an intermittence of action is indispensable in order to secure proper purification.

It may also be of interest to mention that in sandy soils which have been specially prepared for filtering sewage, the under-drains frequently become clogged or obstructed by the growth of a peculiar alga, or fungus, which has been called the sewage fungus. It grows in thick masses, colored yellow, orange, red, brown, or white, depending upon the character of the mineral salts dissolved in the sewage, and its function is to transform the organic matter which is held in solution in the effluent. Its presence is therefore always an indication of incomplete purification ; and it was rarely absent from the effluent drains and ditches of the various sewage farms which I had the opportunity of visiting.

In refutation of what has been said with regard to the sanitary condition of sewage farms and their pollution of the subsoil water, as reliable evidence can be adduced as can be brought for the opposite side. The Paris Commission which was instituted for the investigation of this matter, state that there is a constant odor rising from the farms due to the disposal of sewage by irrigation. Other equally reputable physicians and sanitarians think they have proven the contrary. I had in my pos-

session a report giving very favorable statistics of sickness among the laborers upon these farms; but it must be remembered that a process of natural selection takes place in the choice of such laborers, since there is a general feeling abroad that a sickly person has no business on a sewage farm. On the other hand, paupers are sent to the large farms in troops of hundreds every spring and fall, and among these paupers there is always more or less sickness before being sent out; but we are told that no increase of sickness has ever followed their sojourn upon the farm and the inhalation of the tainted atmosphere, or the use of water from wells upon the premises. In weighing such statements, however, it must not be forgotten that the pauper stays on the ground but a short time and is then taken back to the almshouse, while the regular laborers and superintendents stay there permanently. There can be little doubt that the well-water on such a farm will, sooner or later, become tainted; but it is only after long experience with other than the most robust constitutions that a fair conclusion as to the consequence of the pollution of the atmosphere can be reached. In the cases of Dantzic and the English cities, we must not lose sight of the fact that the same are all located at or near the sea, where the great variations in temperature experienced in the interior of our own country are entirely unknown. What the results of such an intense heat as we had three days (July, 1887) ago would be on a large area heavily irrigated with foul sewage cannot be predicted, and must be determined by experience alone. The questions connected with sewage disposal are of vital importance to all engineers, and I hope that the other members will take them up and express their views fully. I can only say that so far as my observation has gone, I am still in a state of doubt. Agricultural experts of high standing express their doubts as to the pollution of the soil and the subsoil water, and sanitarians of unquestioned repute bear testimony to the pollution of the atmosphere. We are, however, now drawing inferences from conditions that are considerably different from those which obtain in our own land, and hence it is very desirable to have a record of such experiences as the members present who have constructed sewage-disposal works can give.

Without this knowledge of opinions and actual experiences, little can be accomplished. I doubt not but that Mr. Church can give some very interesting information in regard to his experience with sanitarians in relation to the contamination of the Croton water supply.

B. S. Church, M. Am. Soc. C. E.—I am not prepared at this moment to give statistics on this point. I hope to do so at a future time.

The Secretary.—I have been asked also to call the attention of the convention to the paper which has been recently issued in the transactions by our Chairman, Mr. McMath, a very interesting paper upon the determination of the size of sewers, giving results of experiments in

St. Louis with reference to the sewers in regard to the area which they drain.*

Mr. Robert Moore.—I will not discuss the subject which Mr. McMath has discussed so fully, but merely express the wish that other members of the Society who are in a position to observe and record facts in this connection will consider themselves under obligations to present them to the Society. Any one who has undertaken to ascertain what the sewers at any point actually do, the amount of rainfall which actually goes into them, will appreciate the extreme difficulty of the problem. And as there is no way of solving it except by observation, it is a duty of those in a position to make such observations to present them to the Society. I was in part instrumental in inducing Mr. McMath to present this able paper to the Society, and I hope that it may be an example to a great many others.

Mr. Kuichling.—I heartily second what has been said in regard to this matter; it is a duty which the members of the Society owe to each other in this work. Had I known of the existence of Mr. McMath's paper before, I would have been prepared to submit a few facts of some measurements made elsewhere. I hope that those members who have personal experience of this kind, will be generous enough to give us the benefit of it.

The Chairman, Mr. Robert E. McMath.—The suggestion that data and observations be sent to the Society is a good one, and I would say to the members that the facts may very properly be enlarged upon when writing, and they will go into the Transactions.

The question of sewage disposal as it has been discussed here I think may be broadened to advantage. We have been discussing sewage disposal by irrigation and, to some extent, by chemical precipitation. The question as it comes to most of us is not of how we are to use or destroy the sewage, but how we are to get rid of it without nuisance at the least cost. A common practice is to discharge it into a water-course or some body of water. Our western river towns do so, so far as they are sewered, and others will do so. Even now unbearable nuisances have resulted from the practice, and it pertains to engineers to collect and study facts, so as to fix the limits within which such a course is permissible.

It is commonly believed that a stream will purify itself while traversing an undetermined but moderate distance. Of course this must depend upon the proportion of sewage to the minimum volume of the stream, the character and material of the bed, the rate of flow and to mixture with other matter borne by the stream. We, at St. Louis, discharge our sewage into the Mississippi River, and we have supposed,

* Determination of the Size of Sewers. Robert E. McMath, M. Am. Soc. C. E., Trans. Vol. XVI, p. 179, April, 1887.

judging from the results of chemical tests, that pollution practically disappears twelve miles below the last sewer. The ratio of sewage (the discharge of the sewers) to the river volume is small, about $\frac{1}{800}$ at lowest stage; but since the mixture is not complete $\frac{1}{200}$ is a fairer estimate of the actual dilution. The silt carried in the water is doubtless an active agent in the process of purification, but cannot well be estimated. The current at low stages is moderately strong, not far from three miles per hour. Under these conditions the receiving stream is not rendered offensive, except so far as a local discoloration immediately at the mouth of a sewer and detached pieces of floating offal may offend the eye and excite the imagination. Our sister city, Chicago, also discharges her sewage into a body of water which eventually passes into the DesPlaines and Illinois Rivers. The ratio of sewage to lake water is large ($\frac{1}{4}$), and the current in the canal about $1\frac{1}{3}$ miles per hour. At Joliet, 33 miles from the pumping stations at Bridgeport, the nuisance is intolerable at all times, and when the canal and rivers are frozen over the sewage pollution has been observed in disgusting proportion at Peoria, 159 miles from Bridgeport. At Peoria the ratio of sewage to water, river and lake could not have been greater than 1 to 10 at date of observation, January 5th, 1880.

The two cases I have cited present extremes and do little toward determining the very important question: How much dilution and opportunity for aeration must be given sewage in order that it may be disposed of in this manner without causing a nuisance? I think that we would do very well to give a little consideration to that subject. If any one has any facts in regard to the matter, here is a good time and place to present them.

Mr. Stearns.—I do not know that I can give any facts as to the amount of dilution required to prevent a nuisance, but can give some with reference to the pollution of a stream by the discharge of sewage. I refer particularly to the discharge of sewage from the cities of Lowell and Lawrence into the Merrimack River. The population of Lowell is 65 000; of Lawrence 40 000. The dry weather flow of the river is about two thousand four hundred cubic feet per second.

Last summer a series of chemical analyses were made, which showed considerable deterioration in the river water due to the discharge of sewage at Lowell; and the water still contained the bulk of the added impurities when it reached the intake of the Lawrence Water Works about 12 miles below.

A dozen years ago a similar series of analyses were made, and the chemist could not then detect any increase of pollution due to the sewage discharged from both cities.

I am told that at times in the winter, when the river is covered with ice, water from the river, standing in tanks in the houses at Lawrence emits a perceptible odor.

The sewage of Lowell is diluted some three hundred times by the dry weather flow of the river, and the effect upon the river water can be detected by chemical analysis, but it has not yet caused the abandonment of the river as a source of water supply. I think this can be called approximately the outside limit of noticeable contamination.

E. P. NORTH, M. Am. Soc. C. E.—How much of a fall is there between the two cities, and what is the character of the ledge that it flows over? I believe that has a very great influence, whether it is limestone or sandstone.

Mr. STEARNS.—Just below Lowell there are rapids where the water falls 11 feet. Below these rapids the effect of a dam at Lawrence is felt, and the river becomes a narrow mill-pond twenty feet or more deep. The ledge is neither limestone nor sandstone. I do not know its exact character.

It was not practicable to take suitable samples for analysis to determine the influence of these rapids, as they were located so near the City of Lowell, that the sewage did not get mingled with the water of the river until the falls were passed.

Mr. NORTH.—The soil is sandy?

Mr. STEARNS.—The banks are generally a fine sand or silt deposited by freshets.

The Chairman, Mr. McMATH.—What Mr. Stearns has said about the pollution of streams reminds me of another feature presented at Chicago, which arises from the partial decomposition of the sewage in the Chicago River. The condition at Joliet is doubtless worse by far than it would be if the sewage was discharged into the canal fresh and there received a dilution to ¼. The question arises, is the distance to which pollution extends in the river, below Joliet increased or diminished by the partial decomposition effected in the Chicago River? It is proposed to enlarge the channel capacity of the canal and deliver the city's sewage into it in a fresh condition mixed with a larger volume of lake water than now. The towns along the Illinois River want to know whether the tendency will not be to extend the range of pollution—to diminish it in degree, but carry it farther? Also how much dilution they must insist upon as a condition to the privilege sought by Chicago? There is a dearth of facts bearing upon such questions.

Mr. STEARNS.—There is a current in all parts of the Merrimack River, even in the mill pond at Lawrence. I doubt if any odor could be noticed at the river even at an opening in the ice.

Mr. KUICHLING.—In regard to this matter of aeration of sewage, the question must be viewed with reference to the subsequent use of the water by which the sewage is aerated before the measure can be considered allowable. On this subject there are two extreme views, the one

being represented by Dr. Tidy, of England, who places considerable faith in the self-purification of streams, while the other is represented by Dr. Frankland, who says that there is no aeration sufficiently large, and no length of stream sufficiently great, to remove danger, if the water that has been polluted by sewage is used for domestic purposes. Between these two extremes, there is room for a vast amount of argument.

Last fall I attended the Annual Meeting of the American Public Health Association, at Toronto, where the question was raised whether the discharge of the raw sewage of that city into Lake Ontario, at a point several miles distant from the water-works' intake would be likely to result in the contamination of the city's water supply. Some claimed that an appreciable current flowed westerly up the lake, while others denied the existence of any such current, and insisted, that if there was any current at all, it was easterly, or down the lake. The question was to be voted upon by the tax-payers during the session of the Association, and the members were asked to express their views as to the expediency of the proposed scheme on the day before the vote was to take place, it being hoped that by a favorable expression on the part of the Association, the vote would be somewhat influenced in favor of the construction of the contemplated sewer. Among those present on that occasion, was the distinguished bacteriologist, Dr. George M. Sternberg, who, upon being urged to express an opinion, stated that it might fairly be said that there would be danger to the city's water supply if the sewage were discharged into Lake Ontario, as proposed. What the degree of danger was, he was not prepared to say; he would simply call attention to the fact that while researches on the development of germs had not been carried to any such extent as to warrant a sharp formulation of the problem, yet it was generally conceded that danger existed wherever sewage was thrown into a public water supply. Now, when we meet statements of this kind coming from men of profound learning and cosmopolitan fame, it is reasonable to presume that some danger, however small, does attend such conditions of sewage disposal; but in view of the large array of cases that might be cited where no evil results from the use of sewage-contaminated water have been detected in spite of the closest scrutiny, it behooves governments to conduct the most searching investigations as soon as possible, in order to arrive at definite conclusions upon these sanitary questions which cannot be acceptably solved by civil engineers in active life, and which frequently prevent the execution of much-needed improvements in large communities. To illustrate the opposite side of this question of stream-pollution, it may be mentioned that about twenty years ago, it was stoutly maintained that a dilution of one part of raw sewage in thirty parts of clean water, rendered the latter harmless; that limit was next stretched to one in sixty; it now stands one in three hundred, as advocated by the extreme school rep-

resenting the doctrine of the self-purification of streams by aeration and flow. These figures may not be exactly correct, as they are given from an indistinct recollection of data collected some time ago. Much has been written about the development of pathogenic germs in public water-supplies, but little appears to be yet known about their life-history in large bodies of substantially pure water in a state of rest; and it seems to me that on the answer to this question will a rational solution of this whole matter of sewage disposal greatly depend.

Mr. E. C. Clarke.—In considering what treatment is proper in any given case, it is well, first to decide how much it is necessary to accomplish. Whether it is sufficient simply to avoid causing a nuisance, or whether the greatest possible purity of effluent must be obtained to avoid contaminating a source of water supply. In the former case it usually will be enough to clarify the sewage by removing the suspended solid particles; in the latter case it is necessary also to treat the impurities in solution. This process requires comparatively large areas of of land; but sewage can be so clarified as to cause no offense to the senses by dosing small areas of land more heavily than will allow of purification, and also by the use of precipitants which affect but slightly the soluble impurities. I have seen cases in England where a clarified effluent nearly equaled in volume that of the stream into which it emptied, and yet, it was stated, that no nuisance resulted therefrom.

In this discussion it has been somewhat curious to note how difficult it has been to agree upon so simple a fact as, whether, or not, sewage farms commonly are nuisances. I have visited them and think they are not; Mr. Kuichling also has visited them and thinks they are. Certainly, where they have existed for some years people do not seem to be afraid of them. One sees blocks of newly built fine houses, which rent for from five hundred to a thousand dollars a year, standing within one hundred yards of sewage filtration areas. Adjoining the Beddington sewage farm at Croyden I saw a large school for girls, which was said to be full. Surely, parents would not send their girls there if it were exposed to offensive emanations.

It has been proved that sewage can be so purified by filtration as not to contaminate the soil water. In practice, however, owing to mismanagement or carelessness, there may be danger of such result. Still, liability to such danger is not a sufficient argument against the method. The problems in sewage disposal presented to most engineers are: how to avoid, or remedy, offensive and dangerous nuisances and direct pollutions of water supplies by crude sewage. These problems must be solved and remedies applied, even if the processes used do not give perfectly satisfactory results. Surely it is proper to mitigate a nuisance or substitute an occasional slight danger for a constant serious one.

Mr. Kuichling.—I fully agree with all that. I hold, however, that

it behooves an engineer who is called upon to undertake anything of this kind to know what is practicable before he broaches the subject of the construction of a large and expensive plan for sewerage. Any mistake he may make is likely to affect his career later. It is just this point that is up for consideration now, and what I have said was not meant to discourage the construction of works, but to call attention to the circumstance that there is possible danger, and to invite a careful scrutiny of the various conditions that now surround such projects.

It is essential to have these collateral branches of knowledge and science clearly brought out. A civil engineer has usually very little time for personal investigations in these new fields of science, but I think he needs to be fully cognizant of what he is doing, and to see where his mode of sewage disposal is going to lead him. This is especially true of engineers who live in the towns where they expect to spend their lives, or where they have been brought up and whose sewage disposal they are considering. The consulting engineer escapes censure in a great measure; he goes to a place, gives his advice, and then washes his hands of the whole transaction; but the man who stays on on the ground, the city engineer, is the one upon whom all subsequent trouble is going to fall, and therefore it is his business to know what the results will be. And if this fear of soil and water pollution be true, then before he recommends the expenditure of perhaps several millions of dollars for land for the purification of a city's sewage, he must know whether it is nevertheless the best thing that can be done under all of the circumstances attending the case. The eliciting of useful information should be the object of the present debate; and while not dissenting from most of what has heretofore been said by other speakers, it has been my purpose rather to call attention to such facts relating to the sewage question as have been reached from other directions, and to invite thereto careful consideration, for upon us the blame will come if we construct hastily.

With regard to the injection of air into sewage, I may remark that such processes have been tried by English chemists and experimenters without very favorable results. The introduction of air into slightly contaminated water produces some remarkable effects, the water being made sparkling and to some extent pure by this means; but in sewage its action seems to be too slow. The attempts to effect purification therewith were discussed by the English Rivers Pollution Commission, and I remember having read that the experiments were considered as not very successful.

A method was recently proposed of deodorizing the sewage of London, after previous partial clarification by the addition of oxygen in the form of a certain amount of permanganate of potash or soda to every gallon of the effluent. Very good results from that process appear to have been obtained for the conditions of London where they have

160 000 000 gallons of sewage to deal with per day, and where the effluent may be discharged into a large tidal river. The process consists in first treating the sewage with a little less than 4 grains of lime, 1 grain of sulphate of iron per gallon, after which the effluent is treated with from 1 to 1½ grains of permanganate of soda per gallon. These experiments were made on a large scale and are said to be quite successful. The effluent, however, does not reach the ground water, nor is the river water below London used for drinking purposes. The deodorization of sewage is one thing, while its purification, directly or indirectly, is another. Much hope is entertained of the future use and success of permanganate of soda in the treatment of sewage, as the cost of its manufacture has recently been reduced amazingly, so that its use is now possible in many of the English cities where the sewage must be clarified before being admitted into streams.

Mr. Church.—How fully is that aeration carried out?

Mr. Kuichling.—The suggestion of aerating the effluent of precipitating or filtering processes has not yet been tried on a large scale, so far as I know; but on small scales good results have been obtained by allowing the effluent to run slowly in very thin sheets over vertical wire cloth frames, thus exposing it to relatively long-continued action of the air. Similar results are also obtained by exposing the effluent to the air in the form of fine spray.

Mr. Stearns.—As I remember the experiments made in England by Dibdin, some were carried on by forcing air into the bottom of tanks containing either crude sewage or the effluent from chemical precipitation; others by forcing the sewage into the air.

No provision was made for taking care of the odor blown out of the sewage, and it made a dreadful stink about the works.

The aeration was carried on for about 18 hours and it produced a considerable improvement in the character of the sewage, not enough, however, to compensate for the time expended and the nuisance created.

Mr. Robert Moore.—I want to add a few words of testimony in the matter that Mr. Clarke has raised in regard to the facts at Pullman. I want to say that when I visited the Pullman sewage farm in November last there was no smell noticeable at all, except from a ditch in which the sewage stood stagnant at some distance from the filtration area, and that, if we had not known the contents of the fluid, I do not think we should have ever suspected what it was.

Mr. L. B. Ward.—In regard to the health of the men employed on these sewage farms, I had occasion to collect some data a year ago, and I found some valuable facts in a report made by a committee of the Royal Agricultural Society of England, who were investigating the best methods of sewage farming practiced in England, and the results obtained through a series of years on a number of model sewage farms entered in competition for the Society's prize. One point noticed was

the death rate of the persons employed on the farms. A table was given in which the death rate was shown to be much lower than for the average population. The death rate was very light, but I cannot just now give you the figures. The committee was composed of practical farmers and scientific men who would notice those points, and also the health of the working horses and cows which are kept in dairies at many of these places; this was noted as being extremely good. I suppose there is a difference in the condition of a farm that is well kept and one that is poorly kept, and this is probably, in some measure, the cause of the difference between the reports made by different persons.

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AN INVESTIGATION
TO DETERMINE
THE STRAINS IN A HOLLOW CAST-IRON DISK, COOLED FROM THE INTERIOR.*

By G. LEVERICH, M. Am. Soc. C. E.

The body of the Thompson 12-inch breech-loading rifle, fabricated at South Boston Foundry, is of gun-metal (refined cast-iron); the casting was hollow with closed breech; it was made with a sinking head, muzzle upward, and cooled upon the Rodman system, initial circumferential strains about the bore being induced. It weighed in the rough about 160 000 pounds. (For description and dimensions, see Report of Chief of Ordnance, United States Army, for 1876, page 96.)

The sinking head was separated from the muzzle of the piece by a cut about 1 inch wide; from this were taken two disks. The first disk, 13.7 inches internal and 44 inches external diameter and 3.68 inches thick, was tested to determine the initial tension of the casting and also the density and tenacity of the metal. For initial tension, a radial cut

* The measurements here recorded were taken December 10th, 1875, and the computations made in June following; this paper, as here presented, was written in November, 1881, and then laid aside. The rings and disk were a part of the Army Ordnance Exhibit at the Centennial Exposition in Philadelphia, 1876, and afterwards of the Army Ordnance Museum in Washington; however, without at either place any designation to show their origin or purpose.

was made in the disk with a planer tool and carefully extended downward, until the metal, still uncut, separated. The broken section was 13.5 inches long and 0.13 inches deep or 4.86 square inches. Comparing the differences in width of the opening thus made, it was deduced, quoting from the Report referred to above, page 100, that the "initial tension" was "18 500 pounds, or in a ratio of 0.533 to the absolute strength of the metal on the exterior." The specimens tested for density and tensile strength were then taken from this disk at points nearly equidistant from each other and numbered in order of their position from the outside towards the center. The results were as follows:

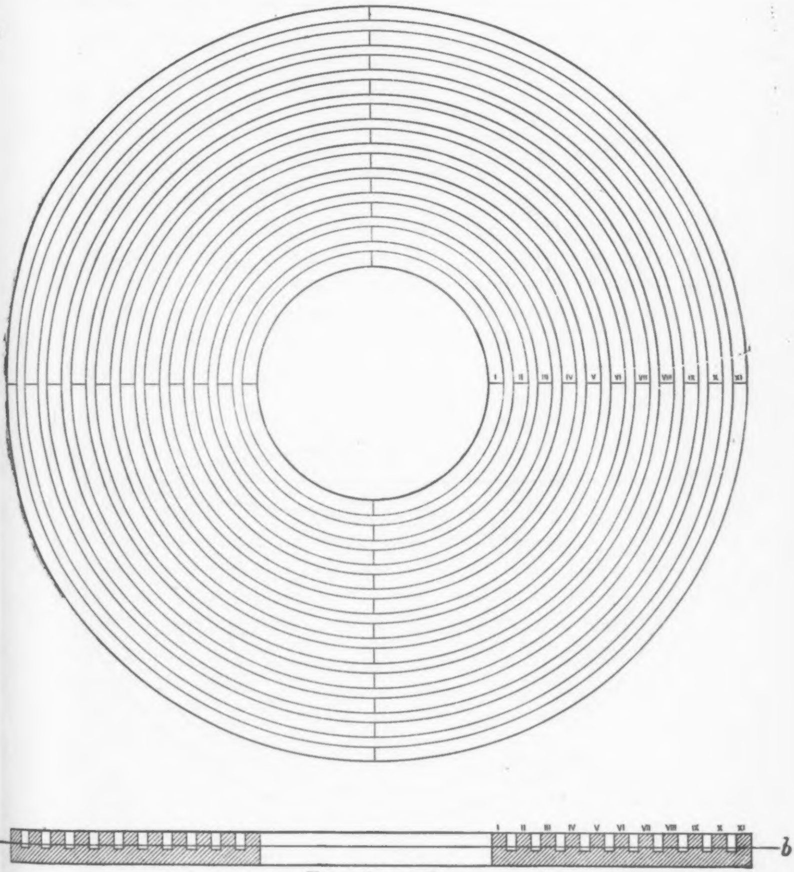
Specimen.	Location in Disk.	Density.	Tensile Strength, per Square Inch, Pounds.
1	Outside	7.2729	34 529
2	Two inches from middle	7.2777	30 746
3	Middle	7 2	29 943
4	Middle	7.2789	29 710
5	Middle	7.2746	29 522
6	Two inches within middle	7.297	34 636
7	Inside	7.29	33 866
	Means	7.2858	31 707

A mean of strength of specimens Nos. 1, 5 and 7, being one each from the outside, middle and inside of the casting, say 32 500 pounds per square inch, more nearly represents the tensile strength of the metal than the mean given above.

The second disk, the subject of this examination, was separated from the first disk and from the sinking head by cuts about one inch wide. It was carefully finished over its entire surface to 13.8785 inches internal and 45.3666 inches external diameter and 2 inches thickness. Then, without removal from the lathe, two diametrical lines at right angles to each other were inscribed on one side of the disk, and ten grooves were turned in, 1.2 inches deep and from 0.573 to 0.606 inches wide, thus leaving eleven rings, from 0.895 to 0.9 inches wide, nearly equally spaced from the inner to the outer edges of the disk and attached to it, as shown by Figs. 1 and 2. These rings were numbered consecutively from the bore outward and then cut (on line *a b*, Fig. 2) from the disk, so that the section of the rings was 0.9 inches square. The cut was so made that a small depth of the grooves remained on the disk, which was reduced to 0.9 inches thickness. After the rings were removed, the disk showed a

slight convexity on its face side. It will be seen that thus were provided for comparison, measures of the metal in the disk at eleven different points, equally spaced from the bore outward and of the metal at these points when detached and free from initial strain.

The measurements were made with a Brown & Sharpe's vernier rule, reading to thousands of an inch. The two diameters in each case were measured and their means taken; rings I, II and III were measured



FIGS. 1 AND 2.

direct; for the others the measure was set to the least diameter of the ring itself or of the corresponding groove on the disk and then applied to the other three diameters, as shown in Fig. 3; with one end of the measure at a, the extremity of the diameter $a\,c$ to be measured, an arc was struck cutting the circle at b and d; the double line $b\,d$ was then measured, and from these two elements $a\,b$ and $b\,d$ the diameter $a\,c$ was computed by formula

$$\overline{ac} = \frac{\overline{ab}^2}{\sqrt{\overline{ab}^2 - \left(\tfrac{1}{2}\,\overline{bd}\right)^2}}$$

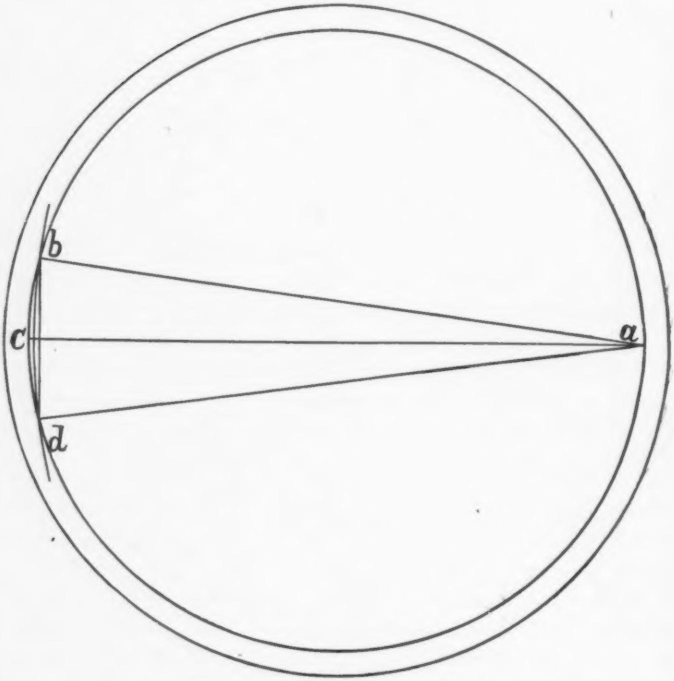


Fig. 3.

This method permitted great precision in measurement, with small possibility of error; since $b\ d$ could readily be taken to the nearest hundredth of an inch, a fractional error less than this would not materially affect the result, and the four diameters for each ring being measured with one length for $a\ b$, whatever small error occurred in taking this length was eliminated when the difference of mean diameters—the quantity sought was obtained. The results of these measurements are given in the following table:

Rings.	Mean internal diameter on disk.	Widths along radius. Inches.		Mean internal diameter of rings.	Differences in mean internal diameters.	Compressions or extensions per inch of circumference.	Strains per square inch necessary to produce these compressions or extensions.
	Inches.	Ring.	Groove.	Inches.	Inches.	Inches.	Pounds.
I.....	13.8785	0.9	....	13.8965	+0.018	+0.00129529	24 000
			0.573				
II....	16.8245	0.9	....	16.838	+0.0135	+0.00080176	16 000
			0.606				
III...	19.8365	0.899	....	19.843	+0.0065	+0.00032757	7 900
			0.6007				
IV...	22.836	0.898	....	24.843379	+0.007379	+0.00032302	7 600
			0.5845				
V....	25.801	0.9	....	25.808397	+0.007397	+0.00028661	7 000
			0.5925				
VI...	28.786	0.899	....	28.784995	—0.001005.	—0.00003492	1 600
			0.5835				
VII. .	31.751	0.896	....	31.747731	—0.003269	—0.00010297	3 200
			0.5825				
VIII .	34.708	0.895	....	34.704503	—0.003497	—0.00009788	3 000
			0.5835				
IX...	37.665	0.899	....	37.662531	—0.002469	—0.00006556	2 300
			0.5765				
X....	40.616	0.898	....	40.605162	—0.010838	—0.00026692	7 400
			0.5825				
XI...	43.577	0.896	....	43.572613	—0.004387	—0.00010068	3 100

FIG. 4.

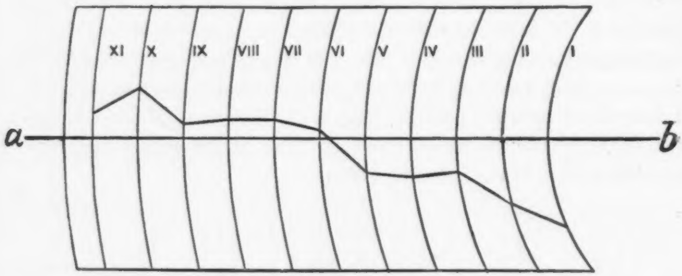


Fig. 4 is a diagram showing comparatively the compressions and extensions in the several rings placed as they were in the disk, and Fig. 5, another diagram showing comparatively these compressions and extensions per inch in circumference of the rings; *a b* is the neutral line.

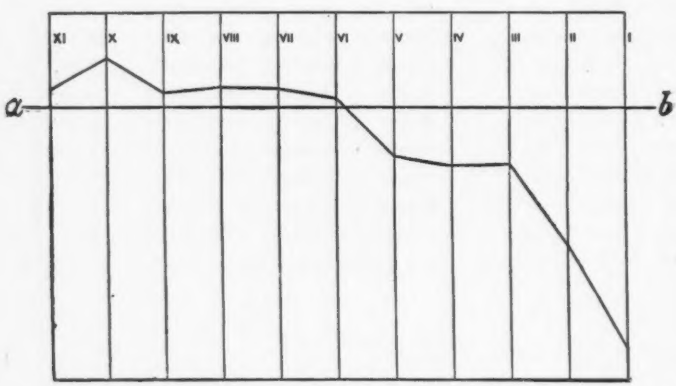


FIG. 5.

In "Reports of Experiments on the Properties of Metals for Cannon," etc., by Captain T. J. Rodman, 1861, page 211 and following, the relative compressions and extensions of cast-iron under strain and of a mean tensile strength of 24 500 pounds per square inch are given. Other and more complete data, resulting from similar tests of gun-metal

of greater tenacity, as now employed, not being at hand, it is assumed that the weights necessary to cause a given compression or extension in specimens of different tensile strengths vary as these strengths; the strains given in the last column of the table are so computed, for gun-metal, having a tensile strength of 32 500 pounds per square inch.

After the diameters of the rings were measured, a radial cut was made in the disk and continued downward until the metal parted; the broken section being 15.744 inches wide and 0.13 inches mean thickness, or 2.047 square inches—which, if the metal broke all at once and not continuously, and its tensile strength was 32 500 pounds per square inch, showed an initial strain of 66 530 pounds in the disk or of 73 920 pounds per inch in the length of the bore. The opening was 0.157 inches wide outside and 0.0555 inches wide inside; referring to the former, it was 0.00110154 inches per inch of outer circumference, which—per data for extension of cast-iron usually taken (Rodman's Report, cited above)—corresponds to between 14 000 and 15 000 pounds per square inch, tensile strain due to shrinkage, and taking data used in last column in the table—corresponds to between 18 000 and 19 000 pounds per square inch, tensile strain, either of which, it will be noted, is far in excess of that recorded in the Table.

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(Vol. XVIII.—February, 1888.)

DESCRIPTION OF THE WORK OF CONSTRUCTING A DAM ACROSS THE POTOMAC RIVER FOR INCREASING THE WATER SUPPLY OF WASHINGTON, D. C.

By SAMUEL H. CHITTENDEN, M. Am. Soc. C. E.

READ FEBRUARY 1ST, 1888.

The water supply of the City of Washington, D. C., comes from the Potomac River, and it is brought into the city through a closed conduit from above the Great Falls, a point about fifteen miles above the city. This conduit was built by the United States Government under the direction of General M. C. Meigs; the first appropriation was made in 1850, and the cost of the work of bringing the water into the city and building storage reservoirs was about three millions and a half of dollars; the conduit is circular in cross-section, 9 feet in diameter, and is built of brick and red sandstone from the Seneca Quarries, about 9 miles above the Great Falls; it passes over a rolling country, requiring high em-

bankments and heavy cuttings; at many points passing through several rock tunnels, and over four stone arch bridges, one, the celebrated Cabin John Bridge of 220 feet clear span; the conduit is well built, but not intended to be used under pressure. The dam at Great Falls that turns the water into the conduit has an elevation of 146 feet 9 inches above mean tide at the Navy Yard, Washington, which is the elevation of the center of the conduit at the upper end, and it has a fall of 9½ inches to the mile.

At a point about nine miles from the Great Falls, the conduit empties into a receiving and storage reservoir, made by building an earthern embankment across the Gunpowder Branch of the Potomac. From the lower end of the receiving reservoir the conduit extends about two miles to the distributing reservoir west of Georgetown; from this reservoir three mains of 12, 30 and 36 inches diameter respectively take the water to the streets of the city. The scarcity of water in the city is due to the small size of these mains and the want of a proper dam at the upper end of the conduit, and not to the size of the conduit or reservoirs.

Afterwards a connecting conduit was built around the receiving reservoir, so that the water supply could be taken directly from the Falls without passing through this reservoir, and so avoid possible contamination from surface water flowing into the Gunpowder Branch, which drains a thickly settled farming community.

As will be seen by an inspection of the accompanying map, the river at the upper end of the conduit is divided by Conns Island into two parts, called the Maryland, and Virginia Channels; much the larger part of the water passes down the Virginia Channel. When the conduit was first constructed, a dam of brush, clay and rip-rap stone was built across a part of the Maryland Channel to divert the water into the conduit; this proving entirely inadequate, the present masonry dam across the Maryland Channel to Conns Island was built, but for several years, in order to keep up the water supply in the low water season, it has been necessary to build temporary dams of brush and earth at the upper end of Conns Island to turn more water into the Maryland Channel.

In 1882, Congress provided for increasing the water supply by constructing a new reservoir east of Howard University and north of the city of a capacity of not less than three hundred million gallons, connecting this with the distributing reservoir west of Georgetown by a tunnel

about four miles long, seven and a half feet by eleven feet in cross-section. From this new reservoir a new system of larger mains was provided for, to reinforce the supply in the old system, and keep up the pressure; also to insure a full supply at all times at the upper end of the conduit, the Act ordered the extension of the masonry dam across Conns Island and the main channel to the Virginia shore, at an elevation of 148 feet above high water, and raising the Maryland Channel dam to the same height by a coping 15 inches thick. The work on this dam is the subject of the present paper.

The plans prepared by the engineer officers, and on which bids were received and contract awarded, provided for a masonry dam across Conns Island, a distance of about 700 feet, and from the island through shallow water, a distance of about 400 feet to Island Rock; also from the Virginia shore out to a point where 5 feet of water was reached; the section on Plate I shows the general features of this portion, the lower side, rock faced, coursed work, no stone less than 3 x 4 feet on the level, with 12-inch rise, and a coping 8 feet 3 inches long, across the dam, and 15 inches thick, no stone for coping to be less than 4 feet wide; two courses of ashlar were put under the coping on the up-stream side, the lower portion of the up-stream face, as well as the center of the wall, was of concrete; concrete was also used to level up for the first course on the face of the dam. The coping was secured to the wall by two bolts of inch and a half round iron, 30 inches long in each stone, while across each joint were set two clamps of 1½ x 1 inch iron, ends turned down 6 inches, and the whole clamp let into the stone. The construction of this masonry dam across the island, and through the shallow water, would leave a gap of about 350 feet of the deepest water; this section it was proposed to close by sinking cribs of sawed timber, afterwards filled with stone, when the bottom was 12 feet or more below the top of the coping; these cribs were to have a length of 24 feet up and down stream; the remainder were to be 16 feet; the other dimensions were to be varied as the bottom might require; the upper ends were to be set on the upper line of the dam, and the tops 3 feet below grade, to allow for a course of stone and coping to correspond with the other dam. After sinking the cribs and filling them with stone, the upper ends were to be covered with a double thickness of planking, and backed up with clay and rip-rap stone. An apron of oak timber was shown on top of the cribs below the coping; it was also provided that the end pens or bins

of the cribs should be filled with concrete, instead of loose stone, so that a good connection could be made between the crib work and masonry dams at each end.

Soon after the execution of the contract for the work at Great Falls, which included the crib dam in the deep water section, it was seen that this was a bad construction, and would not last long, the planking and clay above the cribs, and apron below the coping, would keep the water away from the timber, and allow the whole thing to rot down; the general plan of the crib work, and the conditions, seem to be very similar to those in the dam at Holyoke, Mass., which was repaired with great difficulty and expense, under the direction of Mr. Clemens Herschel, M. Am. Soc. C. E., and described by him in Transactions of the Society for August, 1886, No. 339, Vol. XV, p. 543.

The contractors called the attention of the engineers to this point, and after much discussion and estimates, it was decided that the appropriation was sufficient to build a masonry dam across the deep water section, and the contract was amended, requiring a masonry dam similar to the other. A cross-section is shown on Plate I. It was left to the contractors to decide how this should be accomplished, and the water kept out during construction.

The soundings showed the bed of the river to be rock, and the ledges on the Virginia side above the dam, and below it at the falls, as well as on the Maryland bank, evidently extended under the river. These ledges are composed of the Potomac blue gneiss of varying hardness; some layers soft and largely mixed with soapstone; all stand nearly vertical.

The records showed a long low water season in the summer and fall, but at all times liable to sudden rises from heavy rains, and the river then carried large quantities of heavy drift wood; the current at the site of the dam was rapid, requiring a good oarsman to stem it in a row-boat.

Several plans for excluding the water were considered. The plan adopted was, to first put in a dam of rip-rap stone from the Virginia bank to Island Rock, above the line of the permanent dam, afterwards filling in above the rip-rap with brush and clay to exclude the water. On the down stream side, an embankment of earth was carried out to the deep water, and then an ordinary box coffer dam with a clay filling as shown on Plate I was extended to Island Rock. After completion of the

masonry dam, the top of the rip-rap dam was pulled over against, it making the backing called for by the specifications.

The rip-rap stone was quarried from a bluff on the bank of the river about 400 feet above the Virginia end of the dam—clay of excellent quality, and in abundance, was found in a field 3 000 feet below the dam. A track was laid from the quarry to the dam, and the large stone loaded on small flat cars by horse power derricks, and drawn down to the end of the dam, where a gang of men was kept to unload cars, and keep up, and extend the track; at the same time the smaller stone and quarry chips were loaded by the use of wheelbarrows, on scows carrying about 15 tons each, and unloaded on the upper side of the rip-rap to close the larger holes before putting on the clay. The clay was hauled in carts and wagons to the shore at the end of the dam, and taken out in the scows and on the cars after the stone was in place; the top of the rip-rap was kept at an elevation of about 151, or 3 feet above the completed dam, a height supposed to be sufficient to keep out the ordinary rises of the river, but not the floods caused by heavy rains; the width on top was about 5 feet, as narrow as would carry a track of 3-foot gauge.

The arrangements for handling this material proved very unsatisfactory, and the stone could not be got in place fast enough; unloading the large stone from the cars all over the end, was slow work, and keeping up the track required a good deal of time and attention. We tried to push the rip-rap along by taking out stone on scows to the outer end of the dam; some stone was put in the bottom, ahead of the tracks in this manner, but the current was too swift, and it was difficult and dangerous getting the boats back.

The box coffer dam on the down-stream side was set up as fast as the rip-rap dam was extended, so as to break the current; the timber for posts and stringers and braces for this was cut on Conns Island, and roughly hewed; the general arrangement and sizes of the different parts are shown on Plate I. A small scow 7 feet wide was used for setting up the bents, the scow being moored to the last set of posts set up; its width gave the right distance out to the next set; soundings were taken at the location for each post, and the holes for the tie-rods bored so as to have the lower rod about 15 inches from the bottom of the river, the upper one the same distance below the low water surface of the river, and the center one one-third of the interval between the two others from the bottom rod; the stringers were cut about 10 feet long, and allowed to run past the posts; the sides were then planked in two layers, a 2-inch outside, and common 1-inch board inside, to cover the cracks. The clay was run out from the end of the dam in wheelbarrows, and after it reached the surface of the water, it was tamped with poles to consolidate it.

Afterwards, as the water was pumped down, braces were put in from the rip-rap dam to each post in the deeper water; through carelessness two of the posts used were of poplar, and the lower bolts, with ordinary cut-washers under the heads, were pulled through the posts, and allowed the bottom of the dam to bulge in at these points; additional braces were put in, and no serious trouble resulted.

Very heavy rains the middle of June, and again early in July, caused very high water in the river, carried away the track, tore down the upper part of the rip-rap, and broke off the outer end of the frame coffer, and caused at least six weeks' delay and extra work, so that it was late in September before we were ready to start pumping. A 6-inch discharge centrifugal pump, of Andrews' make, with an upright engine and boiler, also an 8-inch discharge Bush centrifugal, driven by a fifteen horse-power traction threshing engine were set up on the lower dam, and an attempt made to remove the water, but unsuccessfully; the water coming in through the seams in the vertical strata of the bed-rock, apparently very little hindered by our summer's work at damming; additional teams were put on hauling clay, and large quantities put in on both sides; on the lower side it was banked up against the side of the coffer, very nearly to the surface of the water; wherever a hole could be detected, bundles of straw were crowded in, and clay put on top; by this means, and the addition of another 8-inch pump, the water was lowered about 8 feet, and the work of building such portions of the deep water section as were accessible commenced. The season was now far advanced and closed, with about 200 feet of this section built, but leaving 150 feet of the deepest part untouched.

While the work of surrounding this section in the Virginia channel was going on, the section through Conns Island, about 700 feet long was completed, leaving a gap of about 400 feet between Conns Island and Island Rock, which it was decided to leave for the water to pass through, till the balance was completed. As soon as the rip-rap dam reached Island Rock, a trestle was built across the 400-foot open space, and a track carried across to transport the stone and material which came from the Maryland side of the river, and the work of building commenced at the Virginia end of the dam, so that when the working season closed, there remained to build 150 feet of the deep water section, about 400 feet between Conns Island and Island Rock, and the 15-inch coping to put on the old dam across the Maryland channel. The tracks, derricks and pumps were removed, and all work suspended for the winter. No particular damage was done by the winter's floods or ice, but the heavy drift brought down by the spring rise, tore down the upper part of the rip-rap in several places, carried out a section of the frame coffer and the trestle work connecting with Conns Island.

In April the work of repairing the damages was commenced; instead of rebuilding the trestle, cribs were sunk about 20 feet apart, and filled

with stone; at a point above the line of the dam, when the water-way was less, heavy stringers laid on these cribs carried the track; these cribs were intended to be used afterwards in the work of deflecting the water from the section below them.

The breaks in the dam were repaired; the 6-inch pump, and one of the 8-inch ones that was old and not very effective were discarded, and two new 8-inch Bush pumps put on, making three in all, and traction thresher engines hired to run them; these engines were found very convenient; a tramway of flattened logs was laid on top of the lower dam, and these engines would run out on it. In rainy weather, and when high water was feared, the pumps and engines could be removed to a place of safety in half an hour, and as quickly replaced; these three pumps were estimated, running at ordinary speed, to throw 10 000 gallons a minute. The leaks were not as bad as they had been the previous season, and the men were more skillful in finding and stopping them; some very large and troublesome ones were found and stopped, fully 40 feet from the outside of the dams.

The season was rainy, causing delay, but no serious damage was done, and this part was completed July 1st.

A few days after the completion of this deep water section, a rise in the river carried away the cribs that supported the track from Conns Island to Island Rock, and that were intended to be used as a support for a dam to turn the water over the completed portion, and out of the gap west of Conns Island.

New cribs were built and sunk, but with great difficulty, the water passing through the gap of 150 feet in width, and a depth of 5 feet, with great velocity. The cribs were built 8 feet wide, 25 feet long, and 9 feet high, of round poles notched at the corners, and secured by $\frac{3}{4}$-inch iron rods at each corner, holding the top and bottom together; a flooring of poles was put in to hold the stone used for sinking. The cribs were put together on a scow, and then the scow with its load let down by ropes from the shore as far as considered safe; wire rope guys were then fastened to the cribs and secured to trees on the island, and the cribs launched over the end of the scow, and allowed to settle down to position by letting out slack on the guys. It was, of course, impossible to move them up stream at all against such a current, and one or two that got too far down stream were abandoned. After the cribs were in place, they were filled with stone, from small scows let down from above along the wire guys; after they were filled, heavy stringers were placed against the upper ends of the cribs, and a planking of 1-inch boards put on; some care was taken to have those boards fitted to the inequalities of the bottom, but no close work was attempted; brush with heavy foliage, and bags of sedge grass, were then put in on the upper side, this of course did not make a tight dam, but it turned the water over the completed portion, and left about a foot of water

on the line of the dam; this was taken in sections of about a derrick setting each, and surrounded with small dams of sand bags and clay, the water thrown out and the dam built from each end of the gap. In this manner about 350 feet more of the dam was completed, except the coping on a portion, and preparations made for putting in the closure of 50 feet, when the weather put a stop to the season's work. Before the building had progressed far enough to raise the water, the place for the closure was selected, the bottom prepared, the concrete foundation and a timber frame work to hold the planking to throw the water through the gap in the coping put in; very little trouble was anticipated here, but the stone came slowly from the quarry, and the work was not pushed, in order to allow as much coping as possible to be set on the old dam; before the closing of this gap raised the water, winter weather commenced a month earlier than the year before.

The winter's floods tore away the upper part of the timber frame work around the closure, so that it was more difficult to get it tight when work was resumed in the spring, but the gap was closed the last of April.

Attention was then turned to the balance of the coping on the old dam; about 300 feet of this, being all the stone that was ready, was set before the last dam was put in in the Virginia channel, and while the water was below the top of the dam, the closing of the Virginia Channel gave a depth of not less than 15 inches of water on the old dam, when there was about 700 lineal feet of coping to set, but by slipping a derrick along on the coping as set, and using sand bags and clay to exclude the water, this stone was set, and the work completed August 1st, 1886.

Materials.

The cut stone for masonry all came from the sandstone quarry owned by the Government at Seneca, 9 miles above Great Falls, and on the bank of the Chesapeake and Ohio Canal; this quarry was purchased by General Meigs for the purpose of obtaining the stone for the conduit; the stone is not as uniform in color as the stone known as Potomac red sandstone, but is a very durable and excellent building stone, and the quarry furnished all the coping required, about seven hundred pieces; the stone was cut at the quarry and taken down the canal on scows.

The stone for concrete was taken from the rip-rap quarry on the Virginia bank; a Blake crusher was set up between the quarry and dam, and the stone taken out in cars. The sand was obtained at first from the bars in the river, but this was found to be too dirty, and it was then brought up the canal from Washington. The cement used was mostly the so-called Cumberland cements "Round Top" and "Shepardstown," the canal being their usual route to market. "New York and Rosendale" was used in the channel section.

The stone, sand, cement and other material were landed on the canal bank, about 500 feet above the conduit, the stone being handled by a derrick worked by horse-power; a track was laid from this derrick to the bank of the river, and the stone, loaded on cars, was run down a scow built for the purpose with a track on deck; the scow was then poled across the Maryland channel and the cars drawn off by a horse on to a track that crossed Conns Island, close above the dam, and then across the trestle or cribwork to the track on the rip-rap dam in the Virginia channel.

I am sorry to say that I cannot give exact figures as to the quantity of material used and the cost of the auxiliary dam in the Virginia channel, but the men were moved from one point to another so much that the different parts could not well be separated.

I estimated that 7 500 cubic yards of rip-rap stone were used in the upper dam, and fully 10 000 yards of clay in all. The pumps were run continuously about one hundred and thirty days, not counting days when delayed by high water. The cost of pumping, including fuel, hire of engines and men was about $4 600, and the approximate cost of building and repairing the auxiliary dam and trestles and pumping for the Virginia channel work was $42 000.

PLATE I
TRANS. AM. SOC. CIV. ENGNS.
VOL. XVIII Nº 377.
CHITTENDEN ON
POTOMAC RIVER DAM